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THE SCENERY

OF

ENGLAND AND WALES.

LONDON: PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
AND PARLIAMENT STREET

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Fig. 31.

View of the N.E. Cliffs of the Peak of Snowdon, forming the S.W. wall of Glas Llyn Cwm—the steepness not exaggerated.

THE SCENERY

OF

ENGLAND AND WALES,

ITS CHARACTER AND ORIGIN:

BEING

AN ATTEMPT TO TRACE THE NATURE OF THE GEOLOGICAL CAUSES, ESPECIALLY DENUDATION, BY WHICH THE PHYSICAL FEATURES OF THE COUNTRY HAVE BEEN PRODUCED.

FOUNDED ON THE RESULTS OF MANY YEARS' PERSONAL OBSERVATIONS, AND ILLUSTRATED BY EIGHTY-SIX WOODCUTS, INCLUDING SECTIONS, AND VIEWS OF SCENERY FROM ORIGINAL SKETCHES OR FROM PHOTOGRAPHS.

BY

D. MACKINTOSH, F.G.S.,

Author of

Papers on Denudation in the 'Quarterly Journal of the Geological Society,' 'Geological Magazine,' 'Intellectual Observer,' &c.

WITHDRAWN

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TO

SIR RODERICK IMPEY MURCHISON, BART.

K.C.B., G.C. St.A. & St.S., D.C.L., LL.D., M.A., F.R.S., F.G.S., F.L.S.
Hon. M.R.S. Ed., & R.I.Ac.,
MEMBER OF THE INSTITUTE OF FRANCE,
DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY OF THE BRITISH ISLES, &c.

Sir Roderick,—With your permission I dedicate this work to you, for the following reasons:—

The extent to which the discoveries long ago announced in the concluding part of your *Silurian System* illustrated the surface-geology of the western part of South Britain, and explained the marine denudation of many physical features, and the marine deposition of extensive beds of drift at the period when an arm of the sea, including the 'Straits of Malvern,' converted Wales into an island.

Your having given a name and a system to a series of sedimentary strata, and interbedded igneous rocks, which form the most striking scenery of the country described in this work.

Your having all along (as is evident from your writings) been guided in your researches by an appeal to Nature, irrespectively of prevailing theories.

Your having persisted, during many changes of opinion, in advocating *efficiency* as the main requisite of a geological cause.

My belief that all theories relative to the denudation of this country must be chiefly tested by reference to the Silurian districts of Wales, the Welsh borders, and the NW. of England.

The attention you have paid to some of my papers on Denudation read before the British Association and Geological Society, or sent to you for inspection.

For these and other reasons I can think of no one to whom I can so appropriately dedicate this work as to yourself, notwithstanding that your views may not coincide with some of the opinions therein advocated.

D. MACKINTOSH.

PREFACE.

The object of this work is in some measure to supply a want which the author believes is still felt by the general geologist, physical geographer, intelligent tourist, and heads of educational establishments, namely a detailed and systematised description of the more definite forms assumed by the natural scenery of England and Wales, and a full consideration of the causes to which they owe their existence, *so far as they are the effects of denudation.* The author would not have ventured upon such a task were it not that his occupation as lecturer on geology, &c., to provincial scientific institutions and schools, has furnished him with opportunities of visiting and revisiting almost every part of England, and a great part of Wales. Until lately, he purposely refrained from reading very much on the subject of denudation, lest a bias should be given to his opinions. On consulting the principal works and papers,* which treat of the denudation of England and

* Among the works which treat more or less of this subject may be mentioned the following:—Conybeare and W. Phillip's *Geology of England and Wales* (denudation of the SW. of England); Lyell's *Principles and Elements* (sea-coast erosion, and denudation of the Weald); Murchison's *Silurian System* and *Siluria*, 4th edit. (denudation of Wales and the Welsh borders); Ramsay's *Geological Survey Memoir on the Denudation of South Wales*, and his *Physical Geology and Geography of Great Britain.* The subaërial

Wales, he has found that their contents are either general, or limited to particular localities, so that his difficulty has not been to steer clear of what has already been written, but to arrange and generalise the complicated results of his own imperfect observations.

I am conscious that many localities worthy of being described have been either omitted or slightly noticed, because it would require several volumes to include a full account of them all. I am likewise conscious that a second and more careful survey of the localities I have visited, and even revisited, would be necessary to the production of a work in all respects satisfactory. But my object will be gained if I have said enough to stimulate the geologist and intelligent tourist to farther observation.

The work has been divided into three books—the first, or introductory book, being on the causes of denudation and origin of natural scenery in various parts of the world, as a preparation for better understanding the true form of the ground, and the conditions under which it may have originated in our own country. The western coast of Ireland, which now probably represents (at least partly) the former sea-shore conditions of the western parts of England and Wales, has been somewhat particularly noticed. The second and main portion of the work has been devoted to a classification, description, and attempted explanation of the various forms or types of scenery in England and

theory has received its most extreme development in Colonel Greenwood's *Rain and Rivers*, and Mr. Archibald Geikie's *Scenery of Scotland viewed in its connection with its Physical Geology*. In the *Quart. Journ. Geol: Soc.*, Professor Jukes has applied the subaërial theory to the denudation of the south of Ireland.

Wales, the principal of which I have been led to include under the heads Escarpments, Cwms (*English* Comb, Combe, Coomb, *Irish* Coom, *Scotch* corry, *Welsh* Cwm), Passes, Longitudinal Valleys, and Transverse Gorges. In the third book (*Excursions*) the different classes of phenomena occurring in particular districts have been viewed in connection, and the subjects treated in a more popular style, for the sake of the general reader.

Since the appearance of my article on the Brimham Rocks, in the 'Geological Magazine' for April 1865, a great number of articles have been written in the same periodical by myself, Professor Jukes, Mr. G. Maw, Mr. Topley, Mr. Wynne, Mr. Kinahan, Mr. Hull, Mr. Green, Mr. Whitaker, Colonel Greenwood, the Rev. O. Fisher, and others. The reader of the 'Geological Magazine' will see that, in some parts of this work, I have quoted myself, though not to an extent exceeding ten or twelve pages. I still advocate the views suggested to my mind while in the field, and it will be found that so far as denudation is concerned, they more or less agree with opinions held by Sir R. I. Murchison, Sir Charles Lyell, Professor Phillips, Mr. C. Darwin, and others.* I have, however, endeavoured to represent fully, and up to the moment of writing, the state of opinion among the advocates of subaërial denudation, that the reader may be able to judge for himself.

I have had great difficulty in obtaining appropriate illustrations. Of many phenomena I took sketches on

* It may be remarked that those surveyors who are the most extensively and practically acquainted with the varied forms and kinds of escarpments, drifts, soils, and sea-coast phenomena, namely, Mr. Hull, Mr. V. Searles Wood, jun., and Mr. Kinahan, are advocates of marine denudation.

the spot, which are faithful as regards outline, steepness of slope, &c., though imperfect as artistic efforts. In the case of other phenomena I have been at some pains to secure photographs in neighbouring towns, the unsatisfactory nature of which, in common with all photographs (the background being generally taken out of focus), I have to a certain extent remedied by superimposing distinct outlines. I have seen few published engravings of much value as regards accuracy of outline, the steepness of the slopes being generally exaggerated, and the *planes* (of great importance in connection with denudation) represented by more artistic (?) wavy or zigzag lines. All the views of scenery have been taken from original sketches, or from photographs. They have all been engraved purposely for this work.

In conclusion I may state that I have written this work under the belief that nothing can be more detrimental to the progress of a science than an attempt to enlist sympathy in favour of a theory on the ground of its being new, or to excite a prejudice against a theory because it is old; that in true science old and new fashions avail nothing; and that an appeal to Nature, irrespectively of schools or parties, ought alone to be the guide of inquiry. If I have been influenced by any principle or rule of investigation, it has been—that in endeavouring to explain a phenomenon, we ought never to overlook the main requisite of a cause, namely *efficiency*, or to forget that though time may develope efficiency it cannot confer it.

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Errata.

Page 91, line 14 from top, *for* slightly *read* nearly.

„ 116, line 11 from top, *for* Shuntingslow *read* Shutlingslow.

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„ 181, line 19 from top, *for* Redruth *read* Liskeard.

BOOK I.

INTRODUCTORY REMARKS ON THE CAUSES OF DENUDATION, AND ORIGIN OF NATURAL SCENERY IN VARIOUS PARTS OF THE WORLD.

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BOOK I.

INTRODUCTORY REMARKS ON THE CAUSES OF DENUDATION, AND ORIGIN OF NATURAL SCENERY IN VARIOUS PARTS OF THE WORLD.

All geologists are more or less agreed that, at a distance from recent theatres of volcanic action, the smaller inequalities of the earth's surface are, in most cases, due to the excavating power of water and ice—in other words, that the present, generally speaking, is not the surface produced by upheaval or depression, but by denudation. Many considerations render it certain that the last upheavals * of the north of Europe, at the close of the glacial and post-glacial submergences, must have converted many horizontal into inclined planes, and left a greater or less number of shallow depressions, while previous upheavals may have given rise to more marked inequalities; but it is still true that the more abrupt and more abruptly-bounded inequalities are mainly the effect of denudation.† The valleys of the south-coast

* The juxtaposition of slowly-subsiding and rising portions of sea-coast, since the glacial period, must likewise have slightly altered the contour of the surface.

† Since the above was written, the Duke of Argyll (*Quart. Journ. Geol. Soc.* vol. xxiv., No. 95) has endeavoured to show that the physical features of Argyllshire are mainly the effect of subterranean forces. So far as South Britain is concerned, the relative amount of superficial inequality resulting from upheaval or depression, and denudation, resolves itself into the following questions:—How far does the inclination of surface correspond with the inclination of the underlying strata? How far have these strata, since they first formed the surface, been covered up by newer deposits, which have been

of East Devon, long ago described by W. Phillips, Conybeare, and Buckland, afford very obvious illustrations of the formation of valleys by excavation. On sailing along the shore, the most ignorant person must at once perceive that the approximately horizontal strata once extended continuously across, for they precisely correspond on both sides of the valleys.

Denudation along Lines of Fault and Fracture.—It is undeniable that many valleys run along lines of fault, and may therefore have had their direction determined, and the 'initiation' of their excavation facilitated by the effect of upheaval or depression. With regard to fractures, which have not disturbed the strata to any great distance around, I think their importance, in a denudational point of view, has been much underrated. Such a winding and bifurcating rent as that which occurs behind the main mass of the High Tor, at Matlock, and such rents as are common in the carboniferous limestone of all countries, would be very likely to become enlarged into ravines, if subjected to the long-continued action of running water, or sea-waves (see *Transverse Gorges*); and the sides of the ravines thus

swept away? How far have inclined strata been rendered more or less inclined since their edges were denuded? and how far, in this way, have surfaces of denudation been modified by upheaval or depression? How far have anticlinal axes, ridges or domes been worn down by denudation? How far have these elevations become valleys, and the adjacent synclinal depressions hills? Though on a large scale, the elevated grounds of England and Wales are more or less the effect of upheaval, I think there can be no doubt, indeed it is simply a matter of fact, that denudation has mainly assailed the parts forced up by subterranean movements, and spared those which subsided, or were left at a lower level. The extent to which ridges and hills have been eaten into by denudation has in some measure depended on the length of time the denuding influence has been at work. The effect of this influence, in the case of many ridges, has been very unequal. In the Mendip anticlinal, for instance, denudation has spared Black Down, and other central parts, while it has scooped the Vale of Winscombe out of the very heart of the upheaved mass of strata.

formed might exhibit little or no disturbance in the corresponding position of the strata. Even in comparatively solid hills, like the Malverns, there are many fissures filled with trap breccia, &c.* These represent areas of deposition by currents, waves, and possibly by freshwater. Many other fissures, however, may have existed in areas of denudation, and may have been enlarged into valleys. The fact of numerous fractures having become filled up, is no more a proof that other fractures may not have been denuded, and more or less obliterated, than the fact of deposition in one part of a sea-coast, is a proof that another part is not under the influence of denudation. Fractures lying in the direction and course of rapid currents, or exposed on parts of sea-coast undergoing destruction, must have been enlarged; and in the case of fractures previously filled up, the intruded matter may either have been scooped out (as trap dykes are now in course of being scooped out on the west coast of Ireland, &c.), or may have remained while softer rocks on one or both sides were washed away—in either case giving a direction to the denudation.†

Brief Notice of Theories of Denudation.—Hutton and his illustrator, Playfair, were perhaps the first to attempt a philosophical explanation of the excavation of valleys. Playfair believed that there is no part of the land where rivers have not once flowed—that a longitudinal valley consists of two valleys, with their common outlet in a transverse gorge cutting through a ridge—that marine currents cannot form valleys gradually increasing in size from the watershed downwards—that the tidal

* See Dr. Holl's paper on the Malvern Hills, *Quart. Journ. Geol. Soc.*

† Mr. C. Moore has lately discovered numbers of rents in the Mendip Hills filled up with detritus of liassic age. It is impossible to say how many similar cracks may have been effaced by denudation.

inlets on the south coast of England (such as the estuary of the Dart) are depressed land valleys which were excavated by rivers—that the fjords of Norway are river-valleys modified by the sea—that the land rose out of the sea with inequalities which 'initiated' river-valleys—that some valleys have been excavated by oceanic currents, but that they are exceptions to the general rule. He instances the Great Glen of Scotland, which is open at both ends—has straight sides, and a bottom both flat and trough-shaped, with a deep loch; and this depression he regards as an old sea-strait. In doing so, however, he tacitly admitted the marine origin of many passes which did not come directly within the too limited sphere of his observations. As a proof of the lowering of the surface of the land by a widespread process of waste, he referred to the gravels of the midland counties of England, and of Black Down and Haldon, in Devonshire, which he regarded as mere downlettings or leavings of once superincumbent pebbles and flints. At that time geologists were not fully aware that these gravels, especially those of the midland counties, are *drifts*. Playfair took for granted what has since been disproved, namely, that all surface-accumulations and soils represented the breaking up of the rocky frame-work of the land by atmospheric disintegration. In short, he reasoned correctly so far as his premises extended, and it is, I think, obvious from the general style of his work,* that, had he lived at the present day, he would not have joined the ranks of the exclusive subaërialists.†

Of late years Colonel George Greenwood has illustrated Playfair in an extraordinary book entitled 'Rain

* *Illustrations of the Huttonian Theory.*

† A term I first used in the *Geological Magazine* to designate the advocates of atmospheric denudation.

and Rivers,' the main object of which seems to be to show that rain is gradually 'shoving' the whole of the dry land into the sea. He has applied Professor Playfair's *longitudinal valley and transverse outlet* theory to the Weald of Sussex and Kent (which he calls a hill, in opposition to Sir Charles Lyell, who calls it a valley), and has been followed by Professor Jukes, and many of the officers of the Geological Survey. Professor Ramsay, from independent observations, has arrived at similar conclusions concerning the denudation of the Weald, and other analogous parts of England, though he is so far from being an exclusive subaërialist, that his explanations of escarpments and transverse gorges vary according to circumstances, being based on special examinations of the respective areas. This method of dealing with phenomena is exemplified in his valuable work entitled 'Physical Geography and Geology of Great Britain.'

About three years ago, I commenced a series of articles on 'Marine Denudation' in the 'Geological Magazine,' which partly, if not principally, have been the means of exciting an unusually warm discussion. The tendency of this discussion has evidently been to unfold the difficulties with which the subject is beset—the importance of taking nothing for granted—and the necessity for collecting facts, and attaching little importance to theories.

Commencement of Denudation on Unequal Surfaces of Deposition.—It is difficult to say how far the sand-bank table-lands of the Atlantic Ocean are due to deposition, or to ancient inequalities of the sea-bottom; but it seems highly probable that, in main oceans, away from the levelling influence of waves, and in the region of currents, the surface of sedimentary deposits is very uneven. The locally accumulating and excavating action of currents would prevent either the formation or preservation of submarine plains. Mr. Darwin arrived at this conclusion during his voyage round the world, and it is corroborated (on a small scale) by what we know of the arrangement of recent deposits in shallow seas and tidal estuaries, beneath low water level, or in situations where the waves are not sufficiently powerful to obliterate the effects of currents. There the soft, and as yet unconsolidated, strata, are shaped by currents into heights and hollows, ridges and furrows. Were these strata to be elevated, the depressions might become the courses of streams, and by these streams they might be deepened to an indefinite extent.*

Irish Eskers.—The ridges of gravel, &c., called 'eskers,' in Ireland, have been shown, by the Rev. M. H. Close, to be distinct from *drumlins*, or ridges he believes to have been produced by glacial action.† Professor Jukes has for a long time persisted in the belief that eskers have resulted from the action of currents in shallow seas; and this theory of their origin may now, I think, be regarded as established, notwithstanding that Mr. A. Geikie still looks on certain Scotch eskers as mysteries. The resemblance between the arrangement of the elevations and depressions of Irish eskers and valley-systems is very striking. Among the eskers we have the basin or trough (and I think it could be proved that they are not always the result of circumjacent deposition, but

* The bifurcating channels in the muddy beds of shallow seas resemble the ramifications of lowland valley-systems much more than the intersections of rain-ruts on declivities of soft matter. The action of rain on artificial hills of coal-mine rubbish (see chapter xv.), furnishes no illustration of longitudinal valleys, transverse gorges, and passes, while miniature facsimiles of these phenomena may be found in the channels left by currents in the mud or sand of narrow inlets. Since making these observations I have read the following in Darwin's *Journal of Researches*, &c.: 'Mud banks left by the retiring tide imitate in miniature a country with hill and dale.'

† 'General Glaciation of Ireland;' a paper read before the Royal Geological Society of Ireland, March 14, 1868.

often the effect of denudation), the detached eminence, the longitudinal valley, the transverse gorge, and the pass. Both ridges and hollows are in general smoothly rounded, but sometimes the former are sharply edged, while the detached eminences are not unfrequently peaked.* These phenomena, it is true, are on a rather small scale, but for all that we know to the contrary, the great currents of the ocean may be capable of forming submarine inequalities on a large scale, and that both by deposition and denudation. Such inequalities, on reaching the light of day, would begin to be modified by subaërial agencies. During the next submergence, the currents would still farther enlarge the depressions, for though it appears unlikely that currents would commence a channel on a plane surface of consolidated rock of uniform composition, it is but reasonable to suppose that they would be able to deepen and widen previously existing channels. To follow the course of denudation during alternate submersions and emersions of the land, would be going beyond the scope of this work. Neither does it appear desirable to complicate the subject by here considering the relation between old and new denudations, and the filling-up and re-excavation of valleys. Suffice it to say that since the first emergence, the land has probably never gone down beneath the sea with a level or uniform surface, and that during the later periods of geological history, *oceanic denudation has always been impressed on a submerged land-surface of more or less varied contour.* The main object of this work is to trace and describe those peculiar forms of surface-configuration which point to the sea as having been concerned in their formation, not, however, overlooking the effects of rivers, rain, frost, and ice.

* See *Memoirs of the Geol. Survey of Ireland* (Longmans & Co.), explanations to sheets 98, 99, 108, 109, 117, and 118.

Submarine Inequalities.—That the bottom of the sea, where it has long continued at some distance beneath the levelling influence of waves, is very uneven, is a fact known to every student of physical geography. Under the Atlantic there are escarpments, cliffs, table-lands, valleys, basins and troughs; and even in the shallow seas around the British Isles there are very considerable deviations from a uniform surface. In the English Channel there is a remarkable depression in the shape of a long narrow ditch, or rather a series of long narrow pits, forming parts of a hexagonal-shaped circuitous line of deepest water surrounding the British Isles. In the English Channel it embraces North Deep, South Deep, West Deep, and Hurd's Dyke (240 feet deeper than the surrounding ground).* Mr. Everest† refers to the theory that these pits were excavated by a large river, and justly remarks that a river could not have hollowed out troughs with no exit or open passage at each end. He regards them as the remains of ancient cracks or fissures. But I think that a little consideration will show that they are at least partly due to denudation, and that they have been widened, if not entirely formed, by oceanic currents. Currents, as will afterwards be shown, can excavate trough-shaped cavities, while rivers, depending for their motion on an inclination of plane, are incapable of doing so excepting on an exceedingly small scale. Mr. Everest makes it appear that were the bed of the English Channel to be upheaved 180 feet, it would present the appearance of a chain of lakes, somewhat similar to what is now seen in the Great Glen of Scotland. The English Channel has been called a *valley of depres-*

* Off the coast of Lincolnshire it embraces the Silver Pits. Sir Charles Lyell believes that the outer Silver Pits were excavated by currents.

† Paper read before the Geol. Soc. June 19, 1861, by the Rev. R. Everest, F.G.S.

sion, but the meaning of this term, apart from theory, is simply a valley forming a land surface during a longer or shorter period, but so recently submerged that the sea has not had time, by wearing back its cliffs, excavating channels, and depositing silt or sediment, to remove or conceal traces of forests, and other effects of subaërial conditions.

Denuding Ac'ion of Oceanic Currents in Various Parts of the World.—It is very difficult to obtain satisfactory information on this subject. Several eminent scientific travellers and writers on physical geography whom I have consulted, have owned their inability to furnish reliable data. The reader must therefore be left to form his own opinion as to the value of the following statements which have been collected from the best available authorities.

Mrs. Somerville, in her 'Physical Geography,' says that the set of oceanic currents has scooped out the bays and gulfs of the southern and eastern coasts of Asia—that the tidal current, called the Roost of Sumburgh, off the southern promontory of Shetland, runs at the rate of 15 miles an hour (the average velocity of the river Rhone is not a mile and a half an hour)—that there is scarce a strait without a current running in on one side and a counter-current on the other—that currents run at considerable depths,* and are deflected by sand-banks.

Sir John F. W. Herschel on Currents.—This eminent philosopher, in his 'Physical Geography,' speaks of currents in inlets as connecting, joining, rejoining, curving, deflected, reflected, bifurcated, eddying, reacting, shooting, &c. He says: 'The full effect of this power' (the tidal undulation) 'is only to be appreciated when we

* Mr. Carpenter, V.P.R.S., says that in the Arabian Gulf an Antarctic current flows at a depth of not less than 1,800 fathoms.—*Times*, Feb. 22, 1869.

contemplate the rounded forms of hills, and the branching and sinuous valleys of a very large proportion of the surface of the land, where the action of the existing rivers, or any conceivable amount of atmospheric precipitation, is quite inadequate to have performed the work of excavation. Witness our own chalk-downs, much of our Wealden swells and slopes, and the gentle undulations which everywhere cover the surface of the lower land in all countries . . . . and which can be referred to no other agency than tide-washing during a period of prolonged submersion in shallow seas.' According to the same eminent authority, the Caribbean Sea is scoured out by the Gulf Stream* to such an extent as to render its waters intensely transparent.

Captain Beechey† describes a ditch in the North Channel between the county of Down and the coast of Wigtonshire. It is 28 miles long by 1½ wide, and between 400 and 600 feet deeper than the general level of the sea-bottom around it. He regards it as having been excavated by the tidal current, which at its north end flows at the rate of fully 5 knots an hour. Captain Beechey likewise describes a channel in Morecambe Bay, called the Lune Deep, which he refers to the scouring action of the tidal stream.

Denuding Action of Waves in Various Parts of the World.—The connection between ordinary waves and the ground swell, ground sea, or underswell, will be afterwards considered. Meantime it may be observed that in speculating on the origin of the fjords of Norway, it ought not to be forgotten that the ground sea is often so severely felt among the channels, that in the calmest weather they are seldom free from swell and spray.

* This stream, as it issues from Cape Florida, is said to be 30 miles broad and 2,200 feet deep, with a velocity of four miles an hour.

† Royal Society's *Transactions*, 1848.

The steep, and to all appearance recently undermined cliffs which enclose many of the fjords of Norway, afford clear proof of the action of waves more or less assisted by currents. Among these fjords an attentive observer may likewise trace a gradation of channels from a few feet across to several miles, which all present the same shape, and are evidently stages in the process of excavation by waves and currents.

Effects of Waves in Shetland and Caithness.—Sir Charles Lyell, in his 'Principles of Geology,' has brought forward many facts illustrating the action of waves in Shetland and elsewhere. The following I have obtained from Mr. Peach's communication to the 'Geological Magazine.' * 'The cliff on the north side of the Mill Cove of Housay (Shetland) is about 200 feet high; the sea breaks on the *top* of it in heavy gales, and tears up the rock, and also throws up material from the deep. So great is the force, that large blocks are driven far back from the cliff into a large semicircular wall. Between this wall and the cliff, *a deep river-like gully is scooped, down which the water rushes again to the sea.* The water left in the depressions in this gully is brackish, and in it *Enteromorpha* grows . . . . The whole of the top of this cliff (much of it is now beyond the influence of the seas of the present day) is also strewn with proofs of similar action, some of the ridges of stones hanging on the rounded sides of the hills . . . . Every season the terrific seas which break on the whole of these islands leave tracks of their power of the most astonishing kind.' In Caithness the sea piles up fragments of rocks 100 feet above high water-mark.† The stones are not

* Vol. ii. p. 342.

† The high and long ridges of stones thrown up by the sea on the coasts of Caithness, Mr. Peach justly regards as showing the necessity for caution before pronouncing all ridges of angular fragments in hilly districts to be glacial moraines.

rounded, but thrown up in cubical masses like the product of some quarry. The waves in some places run bodily up vertical cliffs to a height of 200 feet.

Effects of Waves on the Coasts of Ireland—Antrim.—On the coast of Antrim there is a great variety of cliff scenery on a magnificent scale. The promontory of Fairhead is 636 feet high. The upper part is a mural precipice, 250 feet high, consisting of basaltic columns, beneath which the slope is strewn with *débris* including large blocks. At the base there is a vast assemblage of fragments of basalt of various forms and sizes, arranged in the most confused manner. They extend down beneath the sea, and are washed by the waves. Nearly the whole coast of Antrim, from the mouth of the river Bush to Bengore Head, consists of a succession of small curvilinear bays surrounded by ranges of basaltic pillars either above or alternating with sedimentary strata of various colours. Among the bays the Giant's Amphitheatre has been regarded as the most beautiful in the world. It is exactly semicircular, and as regular as a work of art. The uppermost part of the encircling cliff consists of a tier of columns 80 feet high, with a rounded terrace between it and another range of pillars 60 feet high, and so on, until at the base there is a semicircle of detached blocks. The whole cliff is 400 feet high (about the height of the nearly perpendicular part of the semicircular and terraced cliff behind Llyn-y-gader, Cader Idris), and the spray is said to rise up to the top. Pleaskin, or Dry Head, is a remarkable promontory. It consists of different beds of basalt alternating with ferruginous and argillaceous strata.

Sea Escarpments of Croaghaun and Slieve League.—'Here, at Saddle Head, commences the loftiest range of sea-precipices in the British Empire. They form a curve, concave to the Atlantic, extending four miles, their highest point being the summit of Croaghaun, 2,192 feet.* As you ascend from Saddle Head, the cliffs become more and more grand; at one point, by estimation about 1,000 feet high, they are nearly vertical, and quite terrific; beyond this they can scarcely be called cliffs, but are immense precipitous slopes, composed partly of rock and partly of grass, but inaccessible to the foot of man. Gigantic ribs or buttresses of rock appear to prop up the mountains, reaching quite to the summit. A little to the north of the highest point, the angle of inclination to the sea is 60 degrees at an elevation of near 1,900 feet. The last mile to Achil Head, the cliffs fall on both sides, leaving a serrated edge, in some places not a foot wide.' Fraser's 'Handbook of Ireland,' p. 494. . . . 'Here (at Carrighan Head) the magnificent range of Slieve-League precipices may be said to begin, which attain an altitude of 1,964 feet,† and then extend to Teelin Head (not marked on the 1-inch Ordnance Map), altogether about 6 miles. Slieve League, like its great rival in Achil Island, is a precipitous rocky mountain, rising from the water at the same angle. . . . Before reaching the highest point a ridge must be crossed, called the One Man's Pass, which is a mere edge, the slope to the sea on one side being nearly 2,000 feet, at an angle which looks almost perpendicular.' *Ibid.* p. 576.

I have not seen either of the above lines of cliff, having for many years had sufficient to occupy my attention in England and Wales; but a very accurate observer, the Rev. M. H. Close, has kindly furnished me with information, maps, &c.

* I have learned from the Rev. M. H. Close that this is the height of the Ordnance survey Trigonometrical point. The highest part of the cliff is 2,202 feet, and the summit of Croaghaun mountain is 2,222 feet, at a distance of about 50 yards from the highest part of the cliff.—*Author.*

† According to the Ordnance Map, 1,972 feet at the Trigonometrical point, which may possibly be a few yards from the brink of the cliff.

Remarks on the Croaghaun Cliffs.—The bottom of the sea, in most places, under the Croaghaun Cliffs, deepens rapidly, and is longitudinally very uneven. The neighbouring cliffs of Keem would appear to be undoubted sea-cliffs. At one place they attain an elevation of nearly 1,000 feet. The ground slopes inland at once from the edge of the cliffs—a clear proof that they are of recent formation, and the sea comes up to their base throughout their whole extent. The narrow edge of Achil Head, Mr. Close admits, is the work of the present sea. He believes that the Croaghaun precipices are now acted on by the sea, and that they have been formed by the sea, assisted by coast-slips, at its present, or at former levels. There are, I think, many facts which show that the Croaghaun cliffs are of marine origin. One is, the abrupt commencement of the brink of the cliffs, totally irrespective of the form of the neighbouring ground. The land-surface from the summit of Croaghaun mountain does not descend uniformly to the sea, but breaks suddenly into the cliff at a little lower level. Farther north, a hollow, containing West Bunnafreva Lake, would appear to have been partly invaded by the receding brink of the cliff, and the lake, scarcely a hundred yards distant, seems on the eve of being drained into the sea. It is certain that the lake-basin was formed long before the cliff-line by which its existence is now imperilled. (2.) There is a talus running into the sea a little to the south of Bunnafreva Lake, which furnishes a strong evidence of the cliff behind it having been undermined by the sea.* (3.) The extent to which the shore-line

* A sloping talus, unless under very exceptional circumstances, presupposes a cliff formed by a cause distinct from that immediately producing the talus. A cause calculated to produce a talus, cannot, as a general rule, form a cliff, because it tends in the direction of levelling down. The cause of a cliff operates in the direction of undermining, and the removal of the undermined materials is a necessary part of its mode of action. It is true that

follows the brink-line of the cliffs, instead of ignoring it, is likewise a proof of the marine origin of the cliffs. The absence of a level terrace-shaped beach beneath the Croaghaun precipices may be due to a peculiar action of the ground-swell, to the circumstance of the land never having remained very long at a stationary level, or to the land having lately subsided. At any rate, it cannot disprove the present existence of sea-coast action, for the undoubted sea-cliffs of Keem and Minaun in the same island (Achil) are nearly equally destitute of a level base line. The Croaghaun cliffs consist of a kind of mica-slate; and the above remarks concerning their mode of formation are more or less applicable to the quartz-rock and greenstone cliffs of Sleive League.

Sea-coast Cwms in Ireland.*—Along the coasts of Ireland there are many approximately semicircular inlets, about the size of Welsh cwms, Irish cooms, and Scotch corries. Being partly under water, and their floors not having been modified by the sea, during a gradual rise of the land, their resemblance to inland cwms may not strike the beholder. But on some parts of the Irish coast there are supra-marine cwms, which descend into the sea. One, called Sause, occurs near Brandon Head. Mr. Close does not regard it as of marine origin. But as the sea generally ignores land-valleys, by barring them up, unless their depth beneath its level be so considerable as to compel it to enter them, and as the line of the shore-rocks to a great extent follows the brink-line of this

the sea can afford to allow a talus to accumulate to a certain extent. The sea may be called a *ruminating* agent. Here and there, it may permit fallen débris to remain, and await its time. But any undermining agency exerted by the atmosphere must come to a termination when a talus begins to accumulate.

* The word cwms (Welsh) will be uniformly used in this work as a name for those hollows which are approximately semicircular or semi-caldron shaped.

cwm, I think it most probable that it has either been directly formed by the sea during a gradual rise of the land, or indirectly by the sea causing a series of coast-slips.

Beachless Shores.—Shores without beaches for greater or less distances are characteristic of the west and north coast of Ireland, the coast of Norway, and the coasts of all archipelagoes. One of the largest continuations or most frequent repetitions of steep shores, is to be found extending from Cape Horn to Behring's Straits. Dr. Hector* has remarked that 'the shores of the intricate channels and inlets on the Pacific coasts of British North America, if elevated from the sea, would present but slight difference from the sides of the narrow valleys in the Rocky Mountains at an altitude of 3,500 feet.' The action of the sea on steep, beachless, and deeply indented shores, must necessarily, in course of time, give rise to phenomena corresponding to the escarpments with irregular base-lines, and subjacent angular drifts, which we find, at intervals, in inland districts.

Denudation of Norway.—The following account of the most striking physical features of Norway (excepting those resulting from glacial action) is condensed from Principal Forbes' work entitled 'Norway and its Glaciers.' About the most common and characteristic depression is a long cleft or gorge, with perpendicular continuous rocky sides of great height (up to 1,500 and even 2,000 feet), a level alluvial flat at the bottom, and an abrupt steep slope at the inner end. The Näroedal is one of the finest specimens. [It is difficult to conceive of such channels having been formed by rivers for many reasons to be stated in the sequel.] The valleys of Norway *do not*

* *Quart. Journ. Geol. Soc.*, vol. xvii.

ramify, but are single. Over their perpendicular or steep sides waterfalls tumble from intervening fields or table-lands. [For one of these waterfalls to have excavated a valley, it must have progressed laterally up an inclined plane.] The valleys resemble streets, their sides house-walls, and the waterfalls rain-spouts. The latter *have not formed* lateral ravines. The mountain system of Norway does not consist of a continuous ridge, but of a row of undulating table-lands at intervals *divided across by passes.* Some of these passes are between 814 and 2,000 feet above the sea. The rivers flow approximately parallel to each other, and *not* in the direction of the greatest declivity of the mountain mass. The main axis of the mountain system of Norway is in places not only on the sea-coast, but has been cut into by the coast-line. The western side of the mountains is in consequence so extremely steep that Principal Forbes seems to refer it (along with other abrupt western sides of continents) to a great cause still involved in mystery. [Whatever the original cause may have been, the encroaching power of the sea would appear to have been the direct agent employed in producing at least part of the effect.] The valleys of Norway resemble fig. 1.; those of the Alps are like fig. 2.

Fig. 1.

Fig. 2.

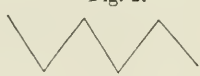


Fig. 3.

Fig. 4.

In England and Wales it would be difficult to say which form predominates—perhaps an intermediate form, fig. 3 alternating with fig. 4. The action of ice, in Norway, has done much, but there are straight grooves running along shore on level ground, and crossing watershed passes, which Principal Forbes believes cannot be the result of glaciers [land-ice].

Denudation of South America and Australia.— The following is a condensed account of some of the observations made by Mr. Charles Darwin in South America and Australia.* Rivers, even large and rapid rivers, are insufficient to transport even ordinary-sized fragments. In Chili there is a narrow strip of land between the Cordillera and the Pacific which is traversed by several mountain lines running parallel to the great range. Between the outer lines and the main Cordillera, a succession of level basins, generally opening into each other by narrow passages, extend far to the southward. 'These basins or plains, together with the transverse flat valleys which connect them with the coast, I have no doubt are the bottoms of ancient inlets and deep bays, such as at the present day intersect every part of Tierra del Fuego, and the eastern coast.' These flat-bottomed valleys and basins contrast with the irregular forms of the mountains. They both bespeak the action of the sea on gently-rising land. In the steep cliffs by which they are bordered there are sea-worn caves. The ridges in which transverse valleys have been cut were once chains of islets. On rising up the tides would always wear deeper and broader channels between them. Mr. Darwin speaks of a dry valley of the grandest dimensions, with bottom smooth and nearly level, as having been left by the sea. He likewise describes enormous accumulations of marine drift, more or less terraced by the sea during pauses in the elevation of the land. According to Mr. Darwin, the summit of the Blue Mountain in Australia is a nearly level plain

* *Journal of Researches made during H.M.S. 'Beagle's' Voyage.* 1860.

which westward attains a height of 3,000 feet. On one side, where the summit is 2,800 feet above the sea, there is an immense gulf, perhaps 1,500 feet deep, thickly covered with forest. It is surrounded by an absolutely vertical line of sandstone cliffs horizontally stratified. It is a quite unbroken amphitheatrical depression about five miles broad. Mr. Darwin regards it as an old bay, the floor of which became covered with sand and wood. It is only one among many others in the same district. Minor bays with narrow mouths run up the sides of the great bays, and almost insulate headlands. 'It is preposterous to attribute these hollows to the present drainage.' [As Australia is a recently emerged area, we are not justified in assigning a *long-continued action* to rains and streams such as that admitted by subaërialists to be necessary to explain the deep depressions of our own country.] The present harbours of Australia have generally a narrow mouth, but they are on a smaller scale than the above phenomena. The theory Mr. Darwin adopts to account for the present forms of these remarkable hollows does not attribute the whole depression to denudation, but supposes that the sea-waves heaped sand around submarine rocks and islands, so as to leave depressions which were afterwards worn back into cliffs during a slow elevation of the land.*

Many volumes might be written on those physical features of other countries which seem to point to the

* In trying to explain the re-excavation of Palæozoic valleys in which Mesozoic strata (such as New Red Sandstone) have been deposited, it is not always necessary to suppose that these strata completely filled up the valleys. They may have been heaped up against the sides of the valleys, and still may have preserved a general horizontality of bedding. In the case of valleys fringed by drifts, such as the valleys which open on the sea-coast in Devonshire, it does not appear necessary to believe that they were ever filled up to a uniform level, though it is certain that the drift now clinging to their sides is only a part of the original deposition.

sea as the main agent of denudation; but to enlarge farther on this subject would be out of place in a work devoted to the natural scenery of England and Wales—a country which is, perhaps, surpassed by no other region of equal size in the world as regards the variety presented by its surface-geology.

BOOK II.

ON THE CAUSES OF DENUDATION, AND CLASSIFICATION AND ORIGIN OF NATURAL SCENERY IN ENGLAND AND WALES.

PART I.

DENUDING ACTION OF THE SEA ON THE COASTS OF ENGLAND AND WALES.

CHAPTER I.

DENUDING ACTION OF TIDAL CURRENTS.

The foregoing facts and considerations, however fragmentary, may be sufficient to prepare the mind of the reader for understanding how far the sea, assisted by or alternating with subaërial agents, may have been instrumental in giving rise to the natural scenery of England and Wales, at periods when the relations between land and water were more or less similar to what they now are in other parts of the world. It is obvious that were we to begin to form our ideas of the ancient action of currents and waves from what we now see on shores which in general lie below the level of the lowest valleys, we should be apt to arrive at erroneous conclusions as to their effects when the higher grounds of this country were islands separated by sounds and channels. It does not, however, follow that a knowledge of what currents and waves are now doing off and on the shores of South Britain, can throw no light on the mode in which it was formerly denuded.

The tidal currents, which here and there impinge on the east coast of England, can scarcely fail, independently of the action of wind waves, to erode the comparatively yielding strata and beds of drift clay and sand.* Along the south coast, though it is certain that such currents as the Race of Portland must be possessed of a certain amount of denuding power, I have not been able to gather any satisfactory evidences that cliffs have been undermined, or pebble-beaches modified independently of the force of waves. It is, however, probable that during spring tides the ebb or back current may at least assist stormy waves in the nearly complete, though temporary, destruction of pebble-beaches which often takes place.

The Rev. S. Haughton † tells us that the tidal streams which enter through the South Channel (between Wales and Ireland) follow the curved outline of Cardigan Bay, directly assail the south end of the Carnarvonshire peninsula, and run through Bardsey Sound. In the Menai Strait the currents flow with great rapidity, and cause numerous eddies.‡ The rocks on the shores, and

* For much valuable information on the action of the sea on the east and south coasts of England, see Lyell's *Principles of Geology*.

† *Journal of the Royal Dublin Society*, vol. i.

‡ I have very lately examined part of this strait. At Garth Ferry, near Bangor, the spring-tide current flows at the rate of about 5 miles an hour. Immediately below the Suspension Bridge I ascertained by experiment that the extreme rate cannot be lese than 7 or 8 miles an hour. Between the Suspension and Tubular Bridges at a place called the *Swelly*, the maximum rate must be between 12 and 15 miles an hour, and among the rapids between the projecting rocks, the rate is sometimes much greater. On a calm day the noise of the current, as it rushes over, or is deflected by the Swelly Rocks, is heard at a distance of three miles. I could not satisfy myself about the *direct* power of the Menai tidal currents to remove stones, but that they can *gradually* do so, is evident from the dilapidated state of a causeway between the Anglesea shore and one of the small islands, north of the Suspension Bridge, in a situation where waves are powerless. The imperceptible grinding power of the currents, which are generally more or less charged with sand, must be considerable; but unlike that of sea-waves wielding stones, it conforms minutely to the structure of rocks, enlarges previously-existing crevices, and produces an effect scarcely distinguishable, excepting by horizontal marks, from that of weathering.

in the bed of this strait, show signs of considerable denudation, which is evidently partly owing to the currents, as the power of waves, especially in the narrow and protected parts of the channel, must be very limited.

Denuding Action of Tidal Currents in the Bristol Channel.—As some parts of England and Wales now more or less inland must at one time have been tidal estuaries, it is desirable that, in a work mainly devoted to inland scenery, the effects of tidal currents in the most remarkable estuary of South Britain, the Bristol Channel, should not be overlooked. Sir H. de la Beche long ago endeavoured to show that the currents of this channel were very powerless, even as regards the transportation of sand; and I have not been able to discover direct proofs that the small shallow current which runs between Bearn Island and Birnbeck Cove, under the new pier, at Weston-super-Mare, is capable of removing stones; but freshwater rivers, excepting where their channels are considerably inclined, afford equally little direct evidence of their power to push stones forward. As far as their ordinary action is concerned, the transportation of stones is a very slow process, and estuarine currents can only differ from rivers, not in their entire inability to translate solid matter, but in the comparatively unfavourable conditions under which they act.* With regard to the Birnbeck current, though it is a poor specimen of even an estuarine current, it has evidently deposited sand on one side of Bearn Island, and must

* Mr. Pooley, F.G.S., of Weston-super-Mare, remarked to me that during the period of his observations he had seen no indication of the tidal current which is divided by the wedge-shaped promontory of Brean Down having worn away the rocks; but I have noticed that the piers of many old bridges have not been abraded by the much-swifter currents of rivers intensified by floods—the marks of masons' tools being often apparently as distinct as when they were first made many years ago.

therefore (as will presently be shown) be capable of exercising a certain amount of denuding power. Many of the currents of the Bristol Channel are more rapid than the one just mentioned. That which darts through the narrow passage called the 'Shoots,' to the south of the entrance of the river Wye, is said to have a velocity of fourteen miles an hour. I have been assured that, in the channel of the Wye near Chepstow, currents have left proofs of their denuding power. In the Bristol New Cut, the amount of denudation, within a given time, can be approximately measured, but there is great difficulty in distinguishing the effects of the current of the River Avon from those of the tidal current. The ebb tidal current, however, has evidently left a loamy deposit mixed with stones on the upper part of the slopes of the New Cut. A farmer, who spent much time in repelling the inroads of the sea to the south of Clevedon, assured me that the stone walls were destroyed by the force of the ebb or back current, as well as by the force of the waves during storms, though I had no opportunity of testing the truth of his statement. At Watchet, a fisherman informed me that he sometimes found stones as large as babies' heads in his nets about a mile out at sea; but as the limit of low water extends to a considerable distance seaward, and as the 'ground sea,' is possessed of considerable power in this part of the Bristol Channel, it might be going too far to attribute the circumstance to currents.* In the lower part of the channel of the River Axe, near Weston-super-Mare, it is obvious that the flow tidal current has excavated little

* Since the above was written, Mr. De Rance (of the Geological Survey) has informed me that he has watched tidal currents moving good-sized pebbles. He has likewise ascertained that even wind, acting on sand dunes, can indirectly transport small pebbles.

coves in the mud banks, as these coves look down, and not up the river.

What is Denudation?—Before proceeding any further with the question of current-action, a definition of the term *denudation* may be necessary. A little consideration will show the necessity of making a distinction between denudation and *disintegration in situ*, though the latter may prepare the way for the former. To be effective, denudation must be something more than the mere downfalling of a cliff, or even the direct erosion of rocks. Carriage, or transportation, must be its main characteristic. Matter must be removed, and a clear vacant space left. Now the transporting power of currents, even to a distance of more than a thousand miles, has been proved; and the fundamental principle of geology, as promulgated by Hutton, is that the great mass of sedimentary strata composing the crust of the earth is a monument of the transporting power of currents. Deposition takes place when the action of currents is at a *minimum*, or in comparatively still water. Where the action of currents is at a *maximum*, transportation is the main office they perform. It would be going too far to say that all, or perhaps the greater part of, the sediment carried by currents was previously held in suspension by the water which became moved into currents; in other words, that currents commence their march *ready laden*; for it could easily be proved that a great part of the matter conveyed by currents is detached from banks, shoals, and deltas, if not from coasts, by currents while in motion. The extent to which shoals with their intervening passages change their forms, where currents run rapidly, and where consequently little deposition takes place, is sufficient to show that currents have the power of detaching as well as carrying. The branching and ramifying forms of many of those submarine passages which are comparatively permanent, and which may be studied on any good chart, are evidently not altogether (perhaps not principally) owing to the deposition of the surrounding ridges, as in all such passages a certain amount of denuding power must be necessary to keep them clear.* From the foregoing remarks I think it results that the denuding power of tidal currents is merely a question of degree.† The action of large and deep currents will be considered in a future part of this work.‡ See *Origin of Valleys*, Chap. XIII.

NOTE.—Since the greater part of this work was written, I had an opportunity of observing some of the effects of the very high tide of Sunday, January 31, 1869, in Morecambe Bay. Though accompanied by very little wind, the tidal current threw down many yards of strong stone walls, breached embankments, destroyed a portion of a line of railway, butchered numbers of sheep, &c. Near Wadhead (Bardsea) it got behind a sloping stone embankment, undermined it seawards, uprooted the stones of an old grass-covered beach, demolished part of a neighbouring wall, and scattered the commingled ruins over a considerable area. In one place it made a breach in a strong sea-wall, forcibly cut out a semicircular mass of stony gravel behind, and carried it back

* On rereading Sir Charles Lyell's *Principles*, I have found this idea differently expressed.

† Since the above was written I have seen the following remarks in an abstract of Mr. Hopkins's *Cambridge Essay* (1857): Before a current of water can put down a quantity of matter, it must manifestly take it up, and moreover, as water cannot, while in a tranquil state, either take up matter or hold matter, however finely divided, in merely mechanical suspension for any length of time, it follows that the operations of denudation and deposition may be regarded as simultaneous operations [in different contiguous areas.—D.M.].

‡ I have very lately (October 1868) observed the rather deep tidal current between Liverpool and Birkenhead, which flows at the maximum rate of quite 7 miles an hour, and have been assured that it is capable of moving leads, at a considerable depth, along a sandy bottom.

through the breach towards the sea. Further south it made considerable inroads on a deposit of very hard boulder clay, and uprooted underlying blocks of limestone from their original planes of bedding. According to newspaper reports, the ravages committed by this tide on the coast at Blackpool were still more striking.

CHAPTER II.

DENUDING ACTION OF SEA-WAVES.

Sea-waves charged with sand, silt, pebbles, fragments, and large blocks of rock, are capable of producing an amount of denudation to which no limit can be assigned. We do not require to imagine their effects, for we have only to open our eyes to see what they are doing on present sea-coasts, what they have done on coasts now deserted, and what they have done where sections have been exposed of coasts of ancient date, which lie buried in the crust of the earth. The land has only to remain at a nearly stationary level to enable sea-waves to accomplish any conceivable amount of horizontal denudation. The land has only to rise or fall to enable them to denude vertically to any conceivable extent. Geology shows that the 'mobility of the land' is so great as to justify the conclusion that there is no peak too high to have been once whitened by the spray of sea-waves—no submarine recess too low to have once formed a shallow estuary. It is true that on any one line of coast the waves are intermittent in their action. At intervals they relapse and sleep, and the shores cease to resound, except perhaps with the slow heavings of the under swell;

but their dormancy only precedes a renewed assault on the foundations of hills which, except in comparison with sea-waves, may be called 'everlasting.' Since the earliest annelides burrowed in the sands of Cambrian sea-shores, these waves have pursued their mighty task of battering down the bulwarks of continents, and they probably shall not cease till they have ridden triumphant over the wrecks of existing mountains.

Wave-action not confined to Sea-cliffs.—In estimating the amount of matter displaced by sea-waves, and rivers such as the Ganges, the fact that wave-action is not limited to the cliff-line has not been sufficiently taken into consideration. In most parts of the world there is a greater or less breadth of tidal zone, and on many of the low-lying shores of our own country this breadth averages from half a mile to a mile. The floor of this tidal zone is frequently rocky, and the rocks are ground down or uprooted and transported when they are not covered with stationary sand, clay, or shingle. But it is on shores consisting of drift-deposits that the displacing power of waves is most strikingly exemplified. The tidal floor at Blackpool, in Lancashire, varies from a quarter to at least half a mile in breadth. It is composed of hard lower boulder clay and loam, in many places covered by recent sand and shingle. The amount of matter displaced by waves on this tidal floor is very much greater than what would be removed along the cliff-line, were the sea now (as was probably the case formerly) to encroach at the rate of a yard in a year. The sea here is scarcely ever free from breakers arising from local winds, or from the ground-swell. The breakers advance in a series of powerful cataracts which closely pursue each other, as if determined that what one leaves undone, should be finished by another. The lines of billowy cascade assail the tidal floor in different directions—at right angles and obliquely. Very frequently two lines rush on with an inclination towards each other until they coalesce. They are often interrupted lengthwise, so as to confine their action to certain parts, which at one time become scooped out into troughs, at another covered with shingle; and all this takes place twice over the same area during the rise and fall of a single tide. In the space of a few hours, an array of foaming cataracts, during their march and retreat, travel twice over the same ground, and every part of this ground is subjected to the action of rushing water in at least four different directions, at right angles and obliquely coastward and seaward. In addition to the action of the sea on cliff-lines, it is therefore clear that in comparing the relative amount of fluviatile and marine denudation and deposition, we must take into account the effects of a series of cataracts varying from a few yards to half a mile, and in many places even a mile in breadth, which sweep round all the windings of all the sea-coasts of the world.

Effects of the Ground-swell.—In speculating on the denudation of sea-shores, the influence of the ground-swell, ground-sea, or under-swell, has hitherto been too little noticed. In this country it is perhaps principally felt on the Cornish coast, but it likewise comes up the English and Bristol Channels, and is very perceptible on the Lancashire coast, as above hinted. In Cornwall it undermines cliffs at a lower level than ordinary wave-action, and excavates caves which are only accessible at low water. It causes the sea to heave, and the level of the sea to rise in harbours, in the calmest weather. It makes a direct entrance into the Bristol Channel, in which its denuding action must be very considerable, though in stormy weather it is often difficult to distinguish its effects from those of superficial waves.

I have not ascertained how far up the Bristol Channel its action is perceptible, but in the neighbourhood of Watchet it is well known to fishermen and sailors. There the tidal zone reaches a breadth of at least three-quarters of a mile. From the base of the cliffs, at high water, to the lowest rocks visible at ebb-tide, the rocky slope is assailed by the ground sea, as well as by the surface waves. At the lowest spring tidal level, its heavings must reach the bottom of a great part of the Bristol Channel. How far the occasional coincidence of its direction with currents and waves of local origin may increase the aggregate of denudation would form an interesting subject for inquiry.

Mode of Encroachment of the Sea in the Bristol Channel.— That the Bristol Channel was a land valley at no very distant period, geologically speaking, is evident from the traces of forest-growth exposed on the tidal zone, and revealed by soundings, where these traces have not been concealed by deposition or removed by denudation. The waves have encroached by originating and wearing back cliffs, and converting a ⌣-shaped valley into a ⊔ -shaped plain. In many places the cliff-line has evidently been worn back so as to impress on a 'valley of depression' the character of a vale of marine denudation. It is generally admitted that Brean Down, the steep and flat Holms, and Weorle Hill, were at one time united by ground either level or more or less undulating; and it seems obvious that a great part of the sea-bottom between these eminences is the effect of marine denudation, either recent or ancient. On the coast to the south of Clevedon, the sea is gradually wearing away the hill, on the northern part of which an old church is situated. It has already, near this church, left only a narrow ridge, and in course of time, probably, no wreck will remain to reveal the fact of the former existence of any part of the hill. The relics of the once-busy population now crowded in the graveyard will be as little respected by the encroaching waves as is the case on many other coasts. Should the whole area become a plain, the fact that a graveyard once existed will have glided into the lowest depths of oblivion, and then the preservation of worm-burrows in the neighbouring sands may be contrasted with the evanescence of man. The outline of the above mentioned hill renders it highly probable that it formerly extended a considerable distance seaward.

At Watchet the mode as well as rate of encroachment

Fig. 5.

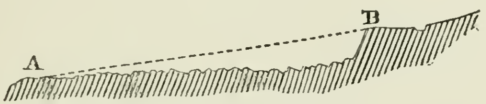


Diagram illustrating the encroachment of the sea near Watchet.

A Stumps of trees. B Present cliff-line. The dotted line A B shows the minimum quantity of rock removed.

can be approximately ascertained. At the distance of at least half a mile (the fishermen say a mile) from Watchet harbour the stumps of trees may be seen at low water. The bottom of the sea between these stumps and the cliff east of Watchet harbour is very rocky. The sea has evidently destroyed the old land surface, and eaten back its cliffs from the stumps to the present cliff-line, which is still gradually receding. The average height of the cliffs is not less than 50 feet. After a few centuries the cliff-line may reach the railway; the waves may then encroach on the rising slope of the hill between Watchet and Williton; after this hill is demolished, the sea-shore for a time will continue low and nearly destitute of cliffs, until the waves commence the task of battering down and carrying away the northern flanks of Brendon Hill.* Should the Brendon table-land ever form the summit of the sea-cliffs, their height will then be equal to that of some of the higher cliffs on the western coast of Ireland. Should the action of the waves in a southerly direction continue, Brendon Hill will not form the limit of the coast-line; but long before the time required for the accomplishment of so magnificent a result, it is possible that changes in physical geography may occur which will give a different direction to, or suspend, the encroachments of the sea on the south coast of the Bristol Channel.

Rate of Encroachment near Watchet.—It may be important, in connection with the subject of the denudation of valleys, to notice the rate of oceanic encroachment in a narrow arm of the sea, such as the Bristol Channel. From the statements of an old fisherman at Watchet, indirectly corroborated by the testimony of other inhabitants, and by legal documents, it would appear that a village called Easenton existed not more than 150 years ago, the most easterly part of the site of which is now at least 400 yards from the cliff. If we suppose the sea to have encroached only 150 yards, the average rate would still be a yard in a year. In asserting the inadequacy of the sea in land-locked situations to wear back its cliffs, subaërialists should recollect that the swell of great oceans frequently extends far inland, and that waves caused by the most local winds are not incapable (time enough being allowed) of wearing back lines of cliff, and hollowing out recesses to a very considerable extent.

Mode of Oceanic Encroachment at Bosham.—In the very narrow and land-locked creeks which ramify from

* See paper by the author, on the Encroachment of the Sea in the Bristol Channel, in *Quart. Journ. Geol. Soc.* vol. xxiv. No. 95.

Bosham Creek, near Chichester, the waves are not incapable of wearing back small cliffs which occur in situations determined by the direction of the winds and tides, and the previous form of the shore. In the same locality the backward rush of tidal waters which have been forced up into small inlets has in several places scooped out little trough-shaped depressions. Some years ago, the back or ebb tidal current, after rushing through a breach in an artificial sea-wall, excavated a trough several yards in depth, and piled up the detritus on the seaward side. It had previously carried away camels and iron tanks filled with stones and earth; and likewise many barrowfuls of rubbish which had been used to dam the sea out from a temporarily reclaimed area.

Mode of Oceanic Encroachment on the South Coast of the Isle of Wight.—Here the sea has not only worn back slopes into cliffs, but breached through the range of chalk hills which at one time must have extended continuously across to the Isle of Purbeck, and of which the 'Needles' are the only lingering wrecks. It is said that the waves, during storms, throw up stones to a height of nearly 500 feet, so as to shatter the windows of the old lighthouse on Needles Point, but I have not had an opportunity of verifying this statement.* For some distance along the south-west coast of the Isle of Wight, the cliff-line runs nearly parallel to the chalk escarpment. Westward, in Freshwater parish, the sea has encroached so far on the chalk hills as to leave cliffs from 400 to upwards of 600 feet in height. This parish may almost be regarded as a peninsula joined to the main island by a ridge called Freshwater Gate. The

* The Rev. Dr. Guthrie, in *Good Words*, assures us that the thick plates of the lanthorn windows of Dunnet Head light-house (Pentland Firth) have been star-cracked by the waves hurling up stones to the height of 300 feet.

source of the River Yar (which is tidal two miles inland) is within a very short distance of the sea. It has even been affirmed that, during storms, the sea breaks over this ridge, and mingles its salt spray with the head-waters of the river. In a few more centuries, as the sea encroaches, the watershed may be driven northwards, and lowered in level until the line of coast reaches the limit of the tidal rise in the River Yar; and if so, the parish of Freshwater will become a small island separated from the Isle of Wight by a narrow sea-strait. Such facts and considerations are instructive in connection with the possible manner in which many sea-straits which have become elevated into land-passes may have been formed by the combination of fluviatile and marine denudation, or by fresh and salt water respectively taking advantage of the share each other may have had in the work of excavation.

Formation of the Undercliff of the Isle of Wight.—The scenery of the irregular terrace (strangely called the Undercliff), with its bounding lines of cliff above and below, is too well known to require a description in a work of this kind. The upper cliff, or rampart of chalk and green sand, is very instructive as throwing light on the mode in which many inland escarpments may have originated. It is true that there is room for difference of opinion concerning the relative share the sea and fresh water may have had in the formation of this remarkable wall of rock; but I think there can be little doubt that if the sea had never encroached on the south coast of the Isle of Wight, the upper line of cliff would never have existed. It is the effect of a coast-slip or series of coast-slips, rather than of land-slips, and may correctly be called an indirect or supra-marine* sea-cliff.

* I believe Sir Charles Lyell was the first to apply this word to certain deposits on sea-coasts, in his *Antiquity of Man*.

Formation of Indirect or Supra-marine Sea-cliffs.—These phenomena are far from being confined to the Isle of Wight; they are common on the south coast of Dorset, Devon, and in every locality where conditions are favourable to their formation. We ought indeed to be cautious in denying that the sea may not have once stood at the level of such elevated escarpments as that to the east of Lyme Regis; but on other parts of the same coast the upper lines of cliff are so near to the sea as to allow us to suppose that they are the effect of coast-slips. Between Lyme Regis and Seaton, a coast-slip in 1839 left a series of well-known cliffs and chasms. Here the sea may be said to have encroached in advance, or to have forestalled its direct mode of action; for though the subterranean percolation of fresh water † prepared the way for the catastrophe, it could not have happened unless the sea had formed a cliff in front, and thereby removed the support which previously prevented the slipping of the land. It is easy to attribute such an occurrence to atmospheric agency, but (excepting on the face of steep slopes) it is obvious that it is only after the sea has held out its arms to embrace the land that any great slip of the latter can take place. The crush-

† The fact seems to have been hitherto almost entirely overlooked that the sea saturates the more permeable strata under cliffs so as to pave the way for their downfall. Mr. De Rance, of the Geological Survey, has just (Nov. 1868) directed my attention to the illustration of this fact furnished by the coast of Kent. He says: 'The underground volume of water beneath the sea-level would always be full from the sea entering the permeable strata and attempting to force its way inwards. The undercliff of Eastweir Bay, Folkestone, no doubt partly owes its origin to this sucking in of the sea at high tides; and the abstraction of the soft beds of the Upper Greensand may have been partly the cause of the local subsidence now taking place at Copt Point.' Mr. De Rance likewise believes that the small springs of the cwms near Folkestone may be the effect of the salt water oozing in from the sea meeting the fresh water which runs down from the land, and forcing the latter up the dip surface of the strata so as to make it issue as a spring on the outcrop of the chalk Downs.

ing and partial displacement of stones by the long-continued weight of the tower and spire of Chichester Cathedral led the way to the memorable catastrophe of 1861; but the true cause of the fall of the superstructure was the removal of Bishop Arundel's stone screen, which supported two of the piers.

Alternate Oceanic Encroachment and Deposition.—Where the coast runs at right angles to ridges separated by valleys nearly on a level with the sea, the waves generally silt-up the valleys, or throw up a bar of sand or pebbles, and wear back the gable-ends of the ridges so as to form a nearly straight coast-line. Of this we find a striking illustration on the south coast of East Devon, where the coast reveals a section of valleys separated by the gable-ends of hills. Where valleys become submerged to a considerably lower level than the surface of the sea, the latter runs into them, leaving the intervening ridges as projecting headlands, as we find at intervals along the coasts of England and Wales, and most other parts of the world. The inlets thus originating, are of course distinct from those immediately resulting from the erosive encroachment of the sea, but it is still possible that they may have been formed by sea currents, if not by waves, at former periods. In the neighbourhood of Aberystwyth, and elsewhere, the sea silts or bars up valleys and wears back the sides rather than the ends of intervening ridges. It makes cliffs out of slopes.*

* Since the above was written I have seen a striking illustration on a very small scale of the tendency of waves to make cliffs out of slopes in proportion to their steepness. In the sands at New Brighton, near Birkenhead, there are oval basins from two or three to twenty feet in diameter. They are much wider, and considerably deeper than their outlets, and one side is steeper than the other. The precise mode of their formation is not easily explained. I had only an opportunity of watching the effect of wave-action on these hollows during the rising of the tide. The waves playfully

From the above facts, it might at first be inferred that the sea is incapable of excavating valleys; but the tendency manifested by the sea to silt-up coast depressions is no more a proof that the sea did not make these depressions, than the filling up of hollows in sand dunes by wind is a proof that these hollows were not scooped out by wind. As on sand dunes wind makes a certain form of ground, and sooner or later destroys it, leaving a totally distinct form; so the sea, on ground which may have been formed by itself, impresses a new configuration, when it meets with favourable conditions. It is quite consistent with these considerations, however, to believe that many ramifying V-shaped ravines, distinct from passes, may have been mainly formed by fluviatile action.

ran up the gentle acclivity, and produced a bold line of cliff on the steep slope, not by directly assailing it, but by a longitudinal sweeping motion. The most noticeable feature was the *gradual* vanishing of the cliff-line as the steepness of the slope decreased.

PART II.

CLASSIFICATION AND ORIGIN OF THE SEA-COAST SCENERY OF ENGLAND AND WALES.

CHAPTER I.

INEQUALITIES AND FORMS OF ROCK-SURFACES UNDER WATER.

Inequalities adjacent to Coasts.—As already observed, *uneven and irregular* slopes under the sea predominate in many parts of the world; and where there is a great depth of water near to the coast, the inequalities are as great as those found at the base of many inland escarpments. But even under the comparatively shallow seas surrounding England and Wales, we meet, at intervals, with considerable irregularities of surface. Along the whole of the south coast, at greater or less intervals, there are natural jetties, piers, or spits, which run out to sea, with intervening depressions. Where they occur under or adjacent to lines of sea-cliffs, and show traces of recent denudation, they cannot be regarded as the mere remains of old land surfaces. Good illustrations of these phenomena may be found on the south coast of the Bristol Channel, in the neighbourhood of Ilfracombe, between Blue Anchor and Watchet, &c. On the latter coast, at short distances from the cliff-line, I observed a succession (along shore) of rocky elevations and depressions, the latter never dry at low water; and on the irregular beach the shingle is often arranged in transverse ridges and hollows. The coast of Devon, between Teignmouth and Torquay, is so irregular under water, and in general so destitute of a level beach-line, that were it to be upheaved, it would be difficult to say at what level the sea had previously stood, unless the exceptional shingle-beaches in the coves could be regarded as a sufficient indication. If those who believe that the sea can *only* leave a level-based coast could reduce their theory to practice in this locality, the population between Watcombe and Torquay would probably soon be doubled, for the comparative absence of level beaches is much felt by visitors.

Submarine 'Screes.'—On those parts of the east coast of South Devon where the base of the cliffs is concealed under water, indications may be detected of the subjacent slopes being strewn with blocks and débris which can never become rounded, and which if upheaved above the sea-level might be mistaken for a subaërial talus, or 'screes,' as such accumulations of angular stones are called in the Lake District. On coasts where the water is much deeper, and the slopes underneath on a larger scale, it is easy to conceive of the existence of submarine screes to almost any extent. (See *Origin of Screes.*)

Rounded, Hollowed, and Grooved Rock-surfaces under High-water Level.—Such surfaces may be seen on almost every sea-coast where the rocks are susceptible of being smoothed, and where the waves can command sand and stones, which are as necessary to enable any natural agency to grind rocks, as emery is in the hands of the glass-grinder. Stones wielded by waves, hollow out depressions which vary in depth from the merest undulations of surface to the through perforation. On limestone coasts perforated blocks—the holes more or less of the shape of a trumpet-mouth—may often be seen with the stones (by the gyratory action of which they were ground out) still remaining. I saw a fine specimen, in the cove under the Bath House, at Torquay, and another (without the stone in the hole) on the top of the cliffs at Petitor, to the north of St. Mary's Church, at a height of more than 200 feet above the sea. Grooved rock-surfaces under high water may be seen on nearly all coasts, but the finest instances I have seen occur on the rocky beach at Aberystwyth (Lower Llandovery sandstone and shale) where the to-and-fro motion of stones driven by the waves is constantly grinding out smooth and regularly-shaped oblong troughs, which are more or less parallel. At low water the stones may be seen resting in the hollows, awaiting the rise of the next tide. Circular or basin-shaped depressions are likewise in course of being ground out by the sea at Aberystwyth and elsewhere.

Honeycombed and Bored Rock-surfaces.—The honeycombed appearance on rocks within the vertical range of waves or spray may be partly referred to chemical (when the rocks are susceptible of chemical influence), and partly to mechanical action. In most cases the structure of the rock, organic or otherwise, would seem to determine the position, and facilitate the process of indentation. Where there is an irregularity in the denudability of the rock, or where small pits already exist, the mechanical force of waves charged with sand or fine shingle tends to grind out minute as well as large holes in rocks. The main difference between pitted surfaces mechanically formed by the sea, and those resulting from atmospheric action, consists in the comparative smoothness and regularity of the former. It is probable that the honeycombed form of limestone rock-surfaces is in a great measure due to marine worms. Mr. E. Ray Lankester, at the Dundee meeting of the British Association (1867), stated the results of his observations, showing that limestone boulders and pebbles on many sea-shores are worm-eaten and riddled by certain species of annelids. The worms are quite soft, and armed only with horny bristles. They bore, according to Mr. Lankester, by means of the carbonic acid and other acid excretions of their bodies, aided by the mechanical action of the bristles. It is well known that larger perforations are produced by boring mollusks.

CHAPTER II.

FORMS OF SEA-BEACHES.

Shingle and Boulder Beaches.—The rounding of stones on the tidal zone between high and low water principally takes place during what may be called the back wave-current, when, on rolling down a slope, they produce a shrill grating sound. The power of such a process to grind off corners is almost infinitely greater than that possessed by rivers and land streams which (except on steep declivities during floods) can only round stones by imperceptibly pushing them against each other, and turning them over. The fragments of certain kinds of rock are too soft or incoherent to admit of being rounded. Others, such as chalk flints, require so long a time to become rounded, even by wave-action, that the duration of one submergence of the land would appear to be insufficient, as proved by the existence of marine tertiary beds of subangular chalk flints. During storms, myriads of stones are thrown up above the sea-level in favourable situations, forming pebble-ridges, such as the well-known Chesil Bank off the coast of Dorsetshire, and the less-known ridge of Northam

Burrows (Barnstaple Bay), concerning the source of which there is some difference of opinion.

To the south of Aberystwyth, near the mouth of the River Ystwyth, the waves have accumulated a large ridge of rounded stones, large and small, and apparently devoid of orderly arrangement. The lower part of this ridge consists principally of large rounded boulders which rest on a bed of stiff clay. For a considerable distance along the coast to the north of Towyn there is an extensive deposit of large rounded boulders mixed with smaller stones, which fills up the space between the base of an inland cliff-line and the present sea-margin. The sea is encroaching on this deposit, and, in some places, has worn its way backwards as far as its ancient boundary. The boulders, in some places, form a wide plateau, and run under the sea. The whole at first suggested to my mind the idea of a manufactory of boulder drift, until it became obvious that the sea was playing with boulders which had previously been rounded and imbedded. In some places, however, at the base of rocky cliffs, blocks are now in course of being detached and rounded by the waves, while the level and uniform surface of the great terrace of boulder drift, leaves little doubt that it was formerly accumulated and arranged by the sea, probably assisted by glacial action, when the land stood somewhat lower than at present.

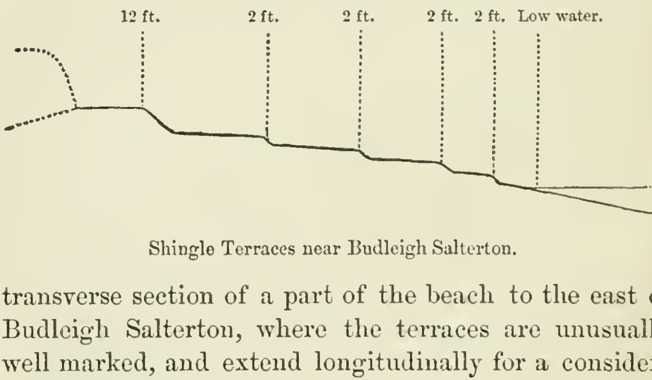
Interweaving of Pebbles with Sand, &c.—I have nowhere noticed more striking evidences of the almost unlimited *versatility* of the sea than on the coast near Aberystwyth. There, during storms and quiescent intervals, the effects of denudation and deposition assume the most varied forms. The sea shows itself capable of mixing stones and sand—heaping up stones in one place, and sand in another; piling up heavier materials on the top of lighter, lighter on the top of heavier; acting in an intermittent manner, so as to produce apparently opposite effects; alternately denuding and depositing in both time and space; leaving heaps of large stones among small, and small among large; laying stones flat, or at any angle, and forcing them up on edge or end; firmly wedging them together or leaving them loose; at different levels and at different times throwing up or laying down different materials, differently arranged in contiguous areas; leaving lenticular patches of sand among heaps of stones, or heaps of stones imbedded in sand; leaving pockets or ridges of large stones among small, or small among large; removing large masses of beach one day, and replacing them another; throwing both sand and stones into the most tumultuous confusion, or leaving them regularly arranged. Sections of some parts of the beach near Aberystwyth would, I have no doubt, present facsimiles of drift sections exposed in railway cuttings, in many parts of Wales and the Welsh borders.

Formation of Terraces at different Tidal Levels.—I am not aware that much notice has hitherto been taken of those very instructive phenomena — the terraces which may often be seen on sloping shingle beaches. Mr. Kinahan, F.R.G.S.I.,* describes a series of terraces now in course of being cut out by the sea, in the limestone cliffs of Innishmore, at the mouth of Galway Bay: the uppermost corresponding to the flow of spring tides, the next to the flow of neap tides, the one below to the ebb of neap tides, and the lowest to the ebb of spring tides. In the shingle, or pebble-terraces of the coasts of England and Wales, I have had some difficulty in tracing a correspondence between their forms and different tidal levels. It is, however, certain that were there no tidal rise or fall, these terraces, as a series,

* *Geological Magazine*, vol. iii. p. 337, 338.

could have no existence. They would appear to be accumulated and undermined by waves lingering longer near the same level at the extreme rise and fall of tides than at intermediate stages. The largest terrace, the platform of which is often seen at a higher level than spring tides, is heaped up by waves during storms, and soon after, as the tide falls, undermined in front; and storms have much to do with the formation, number, and obliteration of the terraces under consideration. Striking specimens may be seen to the south of Aberystwyth, where large as well as small stones have been thrown into the form of shelves, and on the south coast of England, near Budleigh Salterton. Fig. 6. is a

Fig. 6.



Shingle Terraces near Budleigh Salterton.

transverse section of a part of the beach to the east of Budleigh Salterton, where the terraces are unusually well marked, and extend longitudinally for a considerable distance.*

* I lately had an opportunity of observing one mode in which a shingle-terrace may be rapidly formed. In Morecambe Bay, near Bardsea, long lines of wave, separated by considerable breadths of glassy sea, approached a part of the shore obliquely. The breaking of the ends of one of these waves on the beach gave rise to a stream which rushed with great rapidity along the shore, making a large groove in the shingle, and throwing up a ridge on the landward side. In this way a long terrace was formed in a few seconds. The rattling noise accompanying the ploughing up of the beach might be heard at a considerable distance. I could not ascertain whether these waves were the expiring efforts of a ground-sea, or merely a form

Imbedding of Angular Fragments in Sand, &c.—On many parts of the coasts of England and Wales, angular fragments, or chips of rock detached by the waves from cliffs, or which have fallen down, become imbedded in, or covered over with sand, silt, or clay, before they have had time to become rounded or even blunted. Instances of this may be seen on the sea-coast to the north of Weston-super-Mare, and I have no doubt instances on a much larger scale might be found in other parts of this country. Dr. Haast ('Quart. Journ. Geol. Soc.', November 1867, p. 348) remarks that on the coast of New Zealand, 'huge blocks, when washed from the cliffs, or fallen from above, when any portion of the latter has been undermined by the waves, are soon buried, in many places, in the marine sand which the southern swell brings incessantly along with it.' It is only necessary to suppose a gradual subsidence of the land in order to perceive that any extent of angular débris, with a matrix of sand, loam, clay, or earth, might in this way be accumulated.

Block-beaches.—This term may include, not only those heaps or rows of blocks on the tops of cliffs (see *Effects of Waves in Shetland and Caithness*, Introduction) which have been thrown up by sea-waves, but likewise those accumulations of blocks at the base of cliffs which are very characteristic of exposed sea-coasts. In the following, among other localities in England and Wales, the beaches are more or less strewn with blocks:—between Teignmouth and Torquay; at intervals along the whole coast of Cornwall, North Devon, and Wales; on some parts of the south coast, especially to the west of Seaton, &c. Even in the upper part of the Bristol

assumed by the advancing tidal current; but they furnished a striking illustration of the power capable of being exerted by a cause so insignificant as a wave not more than a foot in height, on a perfectly calm day.

Channel, between Blue Anchor and Watchet (triassic alabaster sandstone), and in the neighbourhood of Clevedon (mountain and magnesian limestone) block-beaches occur at intervals.

CHAPTER III.

VARIETIES OF SEA-CLIFF ARCHITECTURE.

Cliffless and Irregularly-cliffed Sea-shores.—On the coasts of England and Wales cliffs are so often absent that it would be difficult to say whether cliffed or cliffless areas predominate. Among the causes of the absence or imperfect development of cliffs may be reckoned a protection from winds, the existence of incoherent drift which does not long retain the cliff form, of crumbling or irregularly fissured or jointed igneous rocks which do not readily receive the cliff form, the presence of strata which slope towards the sea at a certain angle, &c. Where the sea is sufficiently powerful to erode strata dipping towards it, the slipping down of blocks often prevents the formation of a distinct line of cliffs. In localities where the strata are inclined *along shore*, and where the sea is not very powerful, the dip is often followed so as to prevent the formation of a regular or level-based cliff-line. Of this, instances on a small scale may be seen to the south of Clevedon, Somersetshire, where the rock is mountain limestone. In the neighbourhood of Ilfracombe (Devonian slate and limestone) the denudation has been so unequal that were the coast to be deserted by the sea, it would differ little in appearance from the irregularly-cliffed, ridged, hollowed, and peaked rocks on many elevated hill-sides.

Formation of Regular Cliff-lines.—Where the shore is exposed to the full fury of the ocean, the waves often succeed in making regular ranges of cliffs in longitudinally-inclined strata, by a process of oblique denudation. Where the strata dip seawards at a high angle they are generally shaped into fine cliffs, the slope of which corresponds to the angle of inclination. When the cleavage planes are more developed than the planes of bedding, the face of the cliff will coincide with the cleavage dip. Where the sea encroaches along the *upcrop* side of the strike (in which case the strata will appear horizontal along shore), the most regular and perpendicular sea-walls are generally produced. Where the sea is not silting up, where the direction of its action is not diverted by local winds, and where the water is 'deep to,' it often, if not generally, shows a tendency to follow the strike. Where the strata lie horizontally in all directions, the formation and preservation of regular cliffs will mainly depend on the compactness of the rocks, and their ability to withstand gravitation and atmospheric action. Of all these varieties of form the sea-coasts of England and Wales supply numerous instances.

Undercuts.—It is well known that on many parts of the coasts of Cornwall where the bases of the cliffs are submerged, they are indented longitudinally by semi-cylindrical or concave undercuts, over which the rock projects so as to preclude all chance of escape during shipwreck. On the north-west coast of Cornwall the undercut is to a great extent the effect of the 'Atlantic drift,' or ground-sea, which, in the profoundest calm, may be seen steadily and busily at work.

On sea-coasts where rocks are distinctly stratified a phenomenon often occurs, which for want of a better name may be called a *cavernous undercut*. It is something midway between a lengthened undercut and a cave. It is shallow vertically, but often extended backwards and sidewise for some distance. It is mainly formed by reflux wave-action, the rock once occupying the area having been forcibly abstracted. Its roof is generally flat, and both roof and floor frequently dip backwards. It is a common characteristic of the less weathered parts of inland cliffs, as well as present sea-coast cliffs; but wherever found it testifies unmistakably to the violent force of sea-waves.

Caves in Sea-cliffs.—The cliffs of the Cornish coast are perhaps more remarkable than any other in England or Wales for the number and extent of their caves. Many of those on the north-west coast can only be reached at low water, from which it would seem that the under-swell must at least have had the main share in their formation. Near Mousehole, on the south coast, there is a cave 150 feet in length, with an arched entrance 50 feet in height and 30 in width. On the coast of South Wales there are many caves, and the transition between caves now washed by the sea and inland caves may be studied in the peninsula of Gower. Near Tenby there is a very celebrated marine grotto, called St. Catherine's Cave. The principal caves in South Wales are found in mountain limestone. In the same rock, at the base of the Great and Little Ormes' Heads, North Wales, numbers of caves are now in course of being excavated. On the south-west coast of the Isle of Wight many caves have been scooped out by the sea in chalk.* Caves have been excavated by the

* Among the caverns or excavations in the Freshwater range of mural chalk cliffs (3 miles in length, and from 400 to 617 feet high) may be mentioned Freshwater Cave, 120 feet long and 30 feet high, with a roof supported by irregular columns; four caverns in the small recess called Watcombe Bay; Neptune's Caves, the largest of which is 200 feet long; Bar Cave, 90 feet long; Frenchman's Hole, 90 feet long; Lord Holme's Parlour, Lord Holme's

sea in almost every kind of rock; in granite, serpentine, and slate, in Cornwall; in limestone in North Devon, and on the south and north coasts of Wales; in Silurian and Cambrian slates and grits on the west coast of Wales; in new red sandstone (?) on the east coast of South Devon, especially between Torre Abbey and Paignton; in lias on the north-east coast of Yorkshire; in Portland oolite and superjacent strata on the coast of the Isle of Purbeck; in chalk in the Isle of Wight, Flamborough Head, &c.

Horizontal Grooves and Ridges in Cliffs.—Different tidal levels are often indicated on cliffs by horizontal grooves. But where the strata run horizontally, or nearly horizontally, along shore, and consist of hard and soft beds in vertical succession—as near Aberystwyth—they are often fluted or smoothly grooved and ridged over a considerable vertical area. The hollowing, rounding, and smoothing, are effected by sand and stones wielded by the waves as instruments of abrasion during storms. Rough grooves and ridges may likewise be seen near Aberystwyth, at heights or in situations where they are washed by the waves, but are not subjected to a process of grinding. Grooves and ridges, though less regularly defined, may be seen following the local variations in the dip of the strata, on many parts of the west coast of Cardiganshire, where the rocks are of Lower Llandovery age. The edges of the strata of limestone cliffs are much less easily corniced * than those consisting of alternating hard and soft sandstones and shales, though the faces of limestone flags

Kitchen, Roe Hall, &c. In Scratchel's Bay, near the Needles, there is an arched excavation 300 feet in height, which overhangs the beach 150 feet, and, in the neighbourhood, a dark cavern 300 feet in length. The above measurements are from guide-books, and may or may not be correct.

* For sketches of grooves on the Great and Little Ormes' Heads, see Chapter V.

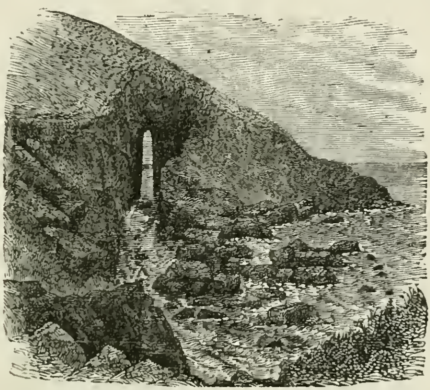
are frequently very uniformly grooved. The new red sandstone between Budleigh Salterton and Exmouth, and in many other localities, very soon becomes fluted by the action of waves, but any form communicated to this rock is soon effaced, and the same remark applies to chalk.

Basin-shaped Cavities.—The sand and stones with which, during storms, the waves are ceaselessly assailing cliffs, are here and there instrumental in rounding prominences and hollowing out cavities. A very small beginning is sufficient to enable the gyratory action of loaded breakers to proceed with the work of grinding out basins of any size or depth, from a few inches up to several yards. The basins are either excavated on horizontal surfaces of rocks, on their slanting or vertical sides, or in the rocky roofs of recesses and caves. Such phenomena are so common on all coasts where rocks are capable of receiving or retaining smoothed surfaces, as to render it unnecessary to specify instances. The most perfect basins are found in limestone and hard fine-grained sandstone, but they are not uncommon in granite. Among the Scilly Islands they are innumerable, and often occur on the vertical or sloping sides of rocks (the Kettle and Pans, for instance), thus throwing light on the origin of many inland rock-basins. (See *Origin of Rock-basins*, Chap. IX. Part IV.)

Perforations and Arches.—It is somewhat difficult to understand the mode in which the sea bores small straight holes through rock masses of considerable thickness, but the fact cannot be disputed. In the cases of holes on a larger scale, the merest crevice is often sufficient to initiate the process. A very remarkable opening has been tunnelled through by the sea in Pendower Point, near the Land's End (see Fig. 7). The openings in projecting parts of cliffs are not only produced by direct erosion, but are often the effect of the bodily removal of jointed blocks. Among the most remarkable instances of arches acting as buttresses to cliffs may be mentioned Durdle Door, west of Lulworth Cove (Isle of Purbeck); the arch of the Parson Rock, between Teignmouth and Torquay; London Bridge, near Torquay; several arches on the south coast of Devon, coast of Cornwall, &c.

Needles, Stacks, &c.—Perhaps the most common sea-coast phenomena are the detached portions of rock

Fig. 7.



Sea-worn Chink, in Pendower Point (Cornwall), called Zawn Pyg.

standing at greater or less distances from lines of cliff, which have been vaguely called Needles, Stacks, Skerries, Hummocks, &c. Their shapes are so varied, and so mutually transitional, as to defy minute description. They are either the remaining harder portions of rocks, the softer or looser parts of which have disappeared, or they owe their existence to the circumstance of the surrounding joints or fractures having diverted the action of the waves, or to causes not well understood. They often lie along the base, or project from the faces of cliffs, but perhaps more frequently stand off headlands in groups, where they appear to be the wrecks of a former seaward extension of the land. There are innumerable well-known instances off and on the coasts of England and Wales. Among them may be mentioned the Needles, to the west of the Isle of Wight; Old Harry Rock, east of the Isle of Purbeck; the rocks off Hope's Nose, near Torquay, &c., &c.

Fig. 8 furnishes an average representation of a sea-coast rocky pillar. It has been left by the removal of adjacent blocks similar to, if not identical with, some of those which lie scattered beneath it.

Fig. 8.

Sea-coast Pillar between Watchet and Blue Anchor, Somerset. (Triassic or Alabaster Sandstone.)

Sometimes an arched buttress and one or more rock-pillars are in near proximity, as in the Parson-and-Clerk Rocks, near Dawlish (Triassic or Permian (?) sandstone).

Where a soft comes under a hard stratum, table and mushroom-shaped rocks are formed, though they sometimes result from special erosion at the highest tidal level. Pinnacles on the summits of cliffs, beyond the ordinary reach of waves, are portions of rock left by the falling down of neighbouring portions through the undermining action of the sea, assisted by the mechanical—and, in some cases, perhaps chemical—influence of spray, and its 'resultant streamlets,'* and atmospheric agency. Mr. Kinnahan has lately shown that rocks are more weathered in the neighbourhood of the sea than further inland.†

How far the Atmosphere denudes Sea-cliffs.—Rain and frost assist gravitation and spray-streamlets in rendering a cliff less overhanging or less perpendicular, by chipping off fragments, and washing away the support received by blocks from the loose matter filling up joints or fractures; but the long-continued action of atmospheric agents tends to destroy rather than to form a cliff; and were the sea not present to carry away the fallen débris, the cliff in course of time would be replaced by a slope, the upper part solid rock, the lower a talus. But in the case of very compact rocks, not dipping towards the sea, rain and frost are not able to throw them down beyond a certain angle. The sea often makes the most steady progress in its encroachments where the cliff runs along the strike, and where the direction of the drainage is away from the cliff. The action of the sea is often impeded where the cliffs fall down too readily; ‡ so that the assertion, often repeated by subaërialists, that the main

* A word happily applied by Professor Jukes to the concentrated action of rain.

† *Geol. Mag.*, vol. v. January 1868.

‡ An attentive examination of the mode of dilapidation by atmospheric agency of the upper boulder clay and middle sand and gravel cliffs north of Blackpool, will, I think, convince any one that the effects of this dilapidation form a great obstacle to the encroachments of the sea, and that were the cliffs to be allowed to retain their steepness, their removal by the sea would be comparatively easy.

part of sea-coast denudation is the work of the atmosphere, is far from being correct.* Effective denudation principally consists in the direct erosion of the bases of cliffs, and the carrying away of the materials, which fall principally in consequence of erosion, and only partly in consequence of atmospheric action. The mere downfalling process, as long as cliffs remain within the dominion of the sea, is a subordinate or accidental part of denudation.

CHAPTER IV.

FORMS OF SEA-COAST INLETS.

Straight and Winding Lines of Cliff.—Where seashore rocks maintain the same structure and composition for considerable distances, and where local currents do not directly assail them, they are often shaped into comparatively straight lines of cliff, such as we find, at intervals, on the south and east coasts of England. On minute inspection, however, it will be found that the straightness, in a great measure, arises from the deposition of silt, sand, or pebble-beds. On many parts of the coasts of England and Wales (south coast of East Devon, coast of Cardiganshire, &c.), the sea wears away elevated grounds, and silts or bars up the intervening low grounds, so as to form an apparently straight line, or curve of large radius. But I think it may safely be asserted that marine *erosion*, apart

* The action of rain and frost on rocks no doubt renders them more easily removed by the sea; but the igneous causes which upheave, dislocate, fracture, and shatter rocks, do as much if not more to facilitate oceanic encroachment, and yet no one would call the latter denuding agents.

from deposition, tends to produce a winding outline, the windings being on a large scale where the rocks are uniform, and on a smaller scale where their structure or composition suddenly varies.

Bays.—There are no considerable-sized curvilinear inlets of the sea, or bays, properly so called, on the east coast of England (Bridlington Bay, perhaps, excepted), or on the south coast, until we arrive at a bay which has not yet received a name—the fine semicircular expanse of water lying between the Bill of Portland and Start Point. On the south and west coasts of England and Wales, the approximately curvilinear bays (not mainly estuaries) are Torbay, Port Isaac Bay, St. Bride's Bay, Fishguard Bay, Hell's-mouth Bay (Carnarvon), &c. These are, to a greater or lesser extent, bays of erosion, and their forms are independent of the mouths of the streams which fall into them. How far any of them have been formed by currents running along-shore, might be worth considering; but wave-action, influenced by the direction of currents and prevailing winds, will probably be found sufficient to account for their denudation. The action of the sea in bays shows a tendency, not very easily explained, to concentrate itself in the direction of one or both sides, so as to dilapidate headlands, or to break them up into detached pillars or rocky projections. There are, likewise, many instances in which a headland has been cleanly decapitated, so as to leave an island separated from the mainland by a strait. But we ought to be careful to make a distinction between these islands and depressed land-eminences, though, it is true, the latter can only be satisfactorily explained as the effect of ancient marine denudation.

Coves.—Bays often include *coves*—a name which will here be limited to small curvilinear inlets of the sea.

The importance of coves in a geological point of view can scarcely be exaggerated, as they are the only phenomena now in course of being visibly formed which bear any real resemblance to the combes of our lower English escarpments, or to the cwms of Wales, and the similar, though not so well-defined, hollows of the Lake District. Hundreds of approximately semicircular coves may be seen on every part of the coast of South Britain; but they principally occur on the south and west coasts, though not nearly in such perfection as in Ireland and other parts of the world. Beginning with the Isle of Wight—Scratchel's Bay (all excavated in chalk), and Alum Bay (excavated in chalk and tertiary beds), furnish good specimens of small coves. On the south coast of the Isle of Purbeck there are several coves. One of them, called Lulworth Cove, has a narrow entrance, like many of the cwms of inland districts. Its two capes consist of Portland stone, and its inner end, about a quarter of a mile from its entrance, of chalk. Its size is, perhaps, about the average of that of inland cwms. Between Dawlish and Parson-and-Clerk Rocks, the railway traveller can scarcely fail to notice one or two small coves excavated by the sea in new red (Permian?) sandstone. A row in a boat between Teignmouth and Babbicombe will enable him to see coast inlets with cwms behind them at a higher level. But the finest specimen of a cove in Devonshire is Anstey's Cove (to the south of Babbicombe), which has been excavated in Devonian limestone. It is a rather large recess with a seaward projection of the cliff, near the middle, which partly divides it into two [how similar to many of the cwms of Wales]. The northern part is entirely the recent work of the sea, assisted by gravitation. The cliffs are about 280 feet high. The southern part, to a certain extent, owes its existence to a northerly prolongation of Kent's Cavern Valley. Along the south coast of Devon, and the south and north-west coast of Cornwall, there are numerous coves. The latter coast has been so much indented, that the capes in many places have been converted into peninsulas with narrow connecting necks of land. In the neighbourhood of Tintagel the coves assume the character of 'gloomy recesses.' Near Cadgewith there is an amphitheatre, entered by the sea through an arch during flood-tides, called the Devil's Frying-pan. It covers nearly two acres, and its cliffs are about 200 feet high. The coast of Lundy Island presents a succession of coves. On the south shore of the Bristol Channel there are numbers of coves, regular and irregular. Those in the vicinity of Ilfracombe and Linton are well known. To the east of Watchet there is a small semicircular cove in course of being continually enlarged. The waves are deflected from its innermost precipice, so as to give them a semi-gyratory motion in the direction of the sides. Further on, towards Doniford Bay, there is a wider cove, in the back cliff of which a fine section of drift is exposed near the top. It would require a whole volume to describe the numerous coves which have been excavated on the coast of Wales. From Carmarthen Bay to some distance beyond Cardigan, the coast is full of them.* Even at Aberystwyth, where the outline of the coast is exceptionally straight, there are several very striking small coves. Between Aberystwyth and Harlech the coast is remarkably uniform; but this arises partly from shore-lines due to deposition, and from the sea encroaching on an old beach of boulder-drift (to the north of Towyn, &c.). On the north-west coast of Carnarvonshire,

* Some of the most regular may be seen on the limestone coast south of Pembroke.

between Bardsey Sound and the Rival Mountains, there is a succession of coves resembling in size and form many of the cwms found at high levels among the neighbouring mountains. In linear and horizontal grouping, the former, of course, differ from the latter as much as continuous and stationary coast-lines differ from interrupted and oscillating coast-lines, such as the Welsh coast-lines must have been during the great glacial submergence.

Supra-marine, or Coast-slip Coves.—A species of cove now in course of being formed at varying heights above the sea-level, may be seen between the Parson-and-Clerk Rocks and Teignmouth, and at Watcombe, in Devonshire. They may be said to have a two-fold origin—first, the original undermining action of the sea causing a cliff; second, the giving way of certain parts of the cliff through gravitation and the action of rain and rain-water saturating the sand and sandstone. These coves very much resemble some of the inland cwms of Devonshire.

Narrow Inlets, Voes, and Creeks.—On every sea-coast where the rocks are jointed or fissured, there are numerous miniature inlets, varying in size from a merely enlarged crevice to inlets corresponding to the width of one or more blocks. The latter are mainly formed by the forcible abstraction of blocks by the sea from the lower part, and the falling down of blocks from above. In many instances, where no fall from above takes place, they retain the form of incipient caves. The existence of similar inlets in inland cliffs furnishes the most demonstrative proof of the former presence of the sea, because the lower blocks must have been moved *en masse* along level, or nearly level, ground—a feat which no one would think of attributing to any form of atmospheric action. Where the structure of the coast is tolerably uniform, the sea sometimes only requires a beginning in the shape of a narrow inlet to enable it to proceed with the excavation of a much larger recess. Caverns of great receding depth often originate in this way, and these caverns, in course of time, become unroofed and converted into *voes*, or narrow passages with perpendicular sides. Among the Shetland Islands the voes are often long and winding. The ordinary waves and the under-swell acquire increased power from their action being confined in these narrow channels, the length of which can only be limited by the force of the winds which give motion to the water. It ought, however, to be remembered, that there is a tendency in the water to rise at the inner ends of inlets, so that it becomes invested with additional scouring power (especially during ebb-tides), by which the excavated débris is carried back into the sea. The Rev. Maxwell H. Close informs me that on the west coast of Ireland there are many creeks a quarter of a mile in length, which have been excavated by the present sea. On the comparatively protected coasts of our own country, it would not be difficult to find narrow creeks (not valleys of depression) quite a quarter of a mile in length; but as in this work the formation of narrow valleys will not be principally referred to *sea-coast* action, it may be unnecessary to specify instances. It may, however, be remarked, that at the time or times when South Britain stood at a much lower level relatively to the sea than at present, its coasts must have been very much more exposed to the unmitigated fury of the 'Atlantic breakers.'

Power of Waves and Currents in Inlets.—I cannot agree with an able and original writer in the

'Geological Magazine'—one of the few who have studied the different phases of the question.* He says, 'the ordinary wave-action along a coast is tolerably equal.' It is only so when every part of the coast is equally exposed to wind. 'The action of waves within an inlet, be it ever so straight and exposed, must always be less than against a headland: a headland is more or less assailable from three quarters, whilst an inlet can only receive the first force of the direct waves.' This is to a certain extent, but, I think, not altogether true. Waves within an inlet, if they lose power in one way, would appear to acquire it in another. As already stated, their force is concentrated, as is evident from the fact that waves are capable of excavating caverns at least 600 feet in length. The very existence of headlands on coasts formed by erosion, not as an exceptional, but as a common phenomenon, is a proof that projections are not more subjected to denudation than inlets. Waves may directly dash against headlands so as to exert comparatively little denuding power, and the circumstances of a headland being assailed from three quarters tends to secure a winding, not a straight line of coast; for two of the directions must tend to deepen the curvature of the bays on each side of the headland, while only one will tend to wear back the projection.† When the smallest recess is formed on a coast, the tendency of wave-action is not to efface it, but to enlarge it. 'With respect to the assumed erosive action of currents, ... motion cannot take place up a *cul-de-sac*—"a cushion of still water" would fill the recess, deflecting the current at its mouth, and thus neutralizing

* Mr. George Maw, F.G.S., vol. iii. pp. 448, 449.

† As already remarked, the lateral action of waves on both sides of a headland would finally tend to break it up, but even then a straight line of coast would seldom be the result.

its excavating power.' This remark does not appear applicable to tidal currents, the motions of which are independent of wind. It is well known that the reflux or sea-ward action of these currents is often very considerable in the narrowest inlets. (See *Denuding Action of Tidal Currents.*)

PART III.

DENUDATION DURING THE GLACIAL AND OTHER SUBMERGENCES OF ENGLAND AND WALES.

CHAPTER I.

PREGLACIAL SUBMERGENCES.

It is at those high altitudes, where we have no reason to believe that the Palæozoic rocks were ever covered up by Mesozoic and Cainozoic deposits, that we may expect to find the surface either as the sea left it in Palæozoic times, or as it has since been shaped by atmospheric action. It is certain that a great part of the denudation of the older rocks took place before the deposition of the old red sandstone, as we find this formation lying in previously excavated depressions. It is equally certain that the old red and carboniferous strata must have been denuded so as to leave the hollows now partly filled up by later formations. The valleys formed by early denudations, and afterwards partly, if not wholly, filled up, must have been re-excavated to a certain depth by comparatively recent denudations. It is difficult to ascertain at what periods all the later denudations occurred—how many times the land may have been under the sea, or how high the sea may have crept up the sides of the hills. We are, however, justified in concluding that wherever we see extensive areas consisting of planed-off edges of strata covered with newer deposits, we have a satisfactory proof of oceanic denudation. But we have no reason to suppose that the sea may not have, at least partly, covered the Palæozoic hills at the time when these newer deposits were formed. The steep slopes of mountains must have been very unfavourable to the accumulation of sedimentary strata, and equally so to the drifting to and fro of stones so as to round them by attrition. The absence of rounded shingle, or ordinary beaches, in many parts of Wales, the Lake District, and the higher grounds of Yorkshire, Derbyshire, &c., is therefore no proof that the sea may not have been there; while the existence of undoubted marine-drifts up to a level of at least 2,300 feet on the Welsh hills (as shown by Professor Ramsay) is a proof that the sea must at least once have been there. We cannot tell how many times the drifts of these elevated regions may have served as shore-accumulations for seas in the depths of which some of our finer sedimentary strata may have been deposited.*

CHAPTER II.

DENUDATION DURING THE GREAT GLACIAL SUBMERGENCE.

It is impossible to tell how far the drifts generally attributed to the glacial period may have been furnished by contemporaneous excavation, or may have been a redistribution of older drifts. It is sufficient for our present purpose to know that they often cover extensive level areas, where, if they even previously existed, they must have been subjected to denudation and re-deposition.

* In the *Geol. Mag.* vol. iv. No. 6, Mr. G. Maw gives a very interesting account of white clays and sands at various altitudes, up to 1.000 feet above the sea, which he believes to be of later tertiary age.

The bulk of the materials of the drifts of England and Wales * are of indirectly local derivation; and we have no reason for supposing, apart from evidences to the contrary, that the cause of their present arrangement was not to a greater or lesser extent the cause which denuded the rocks from which the component parts of the drifts were derived. It may likewise be remarked that a cause equal to the distribution of these drifts must have been possessed of considerable denuding power.

Alleged Dormancy of the Sea during the Glacial Submergence.—Some writers, and amongst them Professor Jukes,† are of opinion that, during the glacial submergence, the sea did next to nothing in the way of denudation. But have we any reason for supposing that the 'calm of desolation' then 'brooded over the face of the deep?' Were the winds then stagnant, and were the billows miraculously enchained, as when the Israelites passed through the Red Sea, for the sole purpose that the marks of ancient pluvial, fluvial, and glacial action might not be effaced? Was there no ground-swell, and were there no rapid currents, at the time when the Welsh and Cumbrian hills were islands, and their passes straits? Is it not more reasonable to suppose that the 'Atlantic breakers' were then more furious, the Atlantic ground-swell more incessant, the Atlantic currents more impetuous, than now? It can scarcely be denied that the deeper an area is submerged, the more the parts above water must become exposed to the denuding action of the sea—of the waves of the open sea around, and of the currents between the islands. The existence of coast-ice, during at least a part of the glacial submergence, would by its transporting power rather assist than diminish the denuding agency of both waves and currents.

* The fine clays and sands at low levels possibly excepted.

† *Geol. Mag.* vol. iii. p. 234.

Ice-marks not Effaced by the Glacial Sea.—The argument against marine-glacial denudation furnished by the preservation of ice-marks which must have been produced during the first glacial period of land-ice, and previously to the glacial submergence, though at first it may appear forcible, gives way on reconsideration. In valleys of depression, such as the Bristol Channel, at the present day, the sea has covered up land surfaces, and preserved the wrecks of forests where valleys open on the coast at a low level; but between these valleys the elevated grounds have been worn back into cliffs. The preservation of ice-marks in certain situations, affords no more presumption against marine denudation than the existence of a buried forest on the shores of the Bristol Channel, at Blue Anchor, furnishes an evidence that between there and Doniford Bay the sea has not worn away an elevated track of land four miles long, and at least half a mile broad, the narrow depression at Watchet excepted. During the glacial and all other submergences, the sea must have denuded and preserved land-surfaces at intervals.*

Marine Drifts regarded as a Measure of Denudation.—In most parts of England, and in a great part of Wales, there are extensively-distributed drifts of the same character, or on the same horizon, with drifts in which

* A good illustration of the destruction and preservation of glaciated rock-surfaces may be seen on the shore of Morecambe Bay, near Baycliff, where the sea is uprooting and removing glacially-smoothed, polished, and striated faces of limestone rock in one place, and covering them up with shingle in another. These rock-surfaces were originally preserved by being covered up with a bed of lower boulder clay (which here immediately after being washed by high tides, such as that of January 31, 1868, exhibits the appearance of distinct stratification, and other indications of marine deposition), while the limestone of Birkrigg Common, in the neighbourhood, either escaped glaciation, or the glaciation must have been destroyed by the sea, which has here left so magnificent an assemblage of wave-hollowed rocks. (See *Preservation of Smoothed Surfaces of Limestone*, chap. xv. part iv.)

sea-shells have been discovered. These shells, if they do not everywhere indicate arctic or glacial conditions, belong at least to post-tertiary times, and may all have been imbedded during some part of the period of the glacial submergence, or during a later submergence. In the Severn Valley, Mr. G. Maw has discovered extensive accumulations of shell-bearing marine drift, which in some parts, as at the entrance to Coalbrookdale, attain a thickness of at least 200 feet—its base being about 100 feet above the level of the present sea.* In the 'Geol. Mag.' (vol. ii. p. 293 *et seq.*) Mr. Darbyshire has described or referred to beds of shell-bearing drift, near Macclesfield, which attains a thickness of from 60 to 70 feet, and which is situated at altitudes between 1,000 and 1,200 feet above the sea—between Blackpool and Fleetwood, on the Lancashire coast, many yards in thickness;† and on Moel Tryfane, near Carnarvon (not the Tryfan Mountain in Ogwen Pass), 40 feet in thickness, at an elevation of 1,350 feet above the sea. In several places sea-shells have been found in the drifts of Staffordshire, Warwickshire, &c.

Marine Drifts of Shropshire and Herefordshire.—I have lately had opportunities of examining railway cuttings in these drifts. Nearly the whole of Shropshire is covered to a greater or less thickness with pebble-beds, sand, or clay (middle sand and gravel and upper boulder clay).† A great part of the drift is of indirectly local deri-

* *Quart. Journ. Geol. Soc.* May 1864.

† Mr. Hull assures us that the lower boulder clay, middle sand and gravel, and upper boulder clay, have been proved by observation to maintain their regularity and order over an area of 600 square miles in Lancashire and the north-east of Cheshire. The middle sand, in some places, attains a great thickness, at Kersal Moor, for instance, probably not under 200 feet. All the three members of the drift present indications of having been accumulated under marine or marine-glacial conditions. Erratics may be found on the hills of North Central England as high up as 1,800 feet. (*Mem. Lit. and Phil. Soc. of Manchester*, 3rd series, vol. ii. 1863–64.)

vation, the stones having chiefly come from Wales or the Welsh borders. Near Coleham (Shrewsbury) it is spread out in extensive sheets with level surfaces, or heaped up into flattened eskers. In one place I noticed it resting in hollows which must have been cleanly cut out of the Permian sand immediately before the drift was deposited, as at the sharp line of contact scarcely a grain of the sand had been displaced. This furnishes a proof of contemporaneous denudation of a very sweeping nature. Between Coleham and Minsterley there is an almost continuous spread of drift, which under a level surface attains a great thickness, while in the knolls, or flattened eskers, it occurs in truly stupendous masses. It is extensively and distinctly stratified, with intercalations of sand, and other signs of accumulation by an agency capable of assorting materials, laying them down in succession, denuding them, re-depositing them in local patches, or uniformly distributing them over wide areas. Near Oswestry, the drift here and there attains a great thickness. In the western part of Shropshire the igneous rocks of the Welsh borders and the eastern part of Wales, especially volcanic ash and greenstone, enter largely into its composition. In the north-east of Shropshire, particularly on the very flat areas, the stones are generally very small, though in many places very large stones may be found. In Herefordshire, I noticed immense accumulations of tumultuously distributed drifts with large boulders. Striking sections are exposed in the railway cuttings between Hereford and Hay.*

Marine Drifts of Wales.—I have lately made a some-

* From the researches of Mr. S. V. Wood, jun., in the east of England (see *Quart. Journ. Geol. Soc.* vols. xxiii. and xxiv.) it may safely be inferred that the enormous accumulations of drift covering the oolitic, cretaceous, and tertiary strata can only be explained by supposing a great amount of marine denudation, accompanied by the action of coast-ice and glaciers.

what particular survey of the rounded boulder drifts in Wales, of local or indirectly local origin, which long ago were accurately described by Sir R. I. Murchison in his 'Silurian System.' These drifts often occupy the table-land summits of hills, or are extensively distributed over plains or slopes in such a way as to preclude any explanation but the action of the sea;* and even where they occur in valleys, it is often clear that the rivers, instead of having produced them, only sport with 'ready-made boulders,' and excavate their channels in previously deposited gravel.†

Marine Drifts of North-West Lancashire.—I have lately made a series of observations on the classification, nature, and origin of the drifts of north-west Lancashire, which are merely an extension of the lower and upper boulder clays and middle sand and gravel of the neighbourhood of Manchester, in which locality they were all regarded by Professer Ramsay and Mr. Hull as marine deposits. From Preston, to the north of Carnforth, along the sea-coast, and extending for miles inland, you encounter an almost constant succession of knolls and

* In North Wales, at Bangor railway station, a section reveals a great thickness of sand (interstratified with pebbles) as finely laminated, as fantastically falsebedded, and in some places nearly as solid, as the sands of our new red sandstone formation. A similar section has lately been exposed on the Anglesea side of the Menai Strait, between Menai Bridge and the monument.

† Since the above was written, I have somewhat particularly examined the enormous accumulations of marine drift, with large boulders, which spread out in plains or smooth slopes along the northern and western side of the Snowdonian range of hills. It has evidently been derived from the hills. The sea could only have derived part of it from valley glaciers, as it forms a nearly continuous expanse, excepting in the passes of Llanberis, Nant Francon, &c., where it has been ploughed out by glaciers. In some places the drift area is at least six miles in breadth. It can be well seen on walking from Port Dinorwic to Marchllyn Mawr. On the northern slope of Elidyr Fach, sea-shells may be found with little difficulty, as I have been informed by the eminent local geologist, Mr. Griffith Ellis, of Llanberis. (For further reference to the Snowdonian drifts, see *Excursions*.)

plateaux of drift. At Blackpool, on the sea-coast, where (as already stated) the drift contains sea-shells, and at Carnforth in a railway cutting, extensive sections have been exposed. The boulders appear as if they had been rounded on sea-coasts, smoothed and striated by coast and ground-ice rather than by glaciers, and transported by coast-ice rather than by icebergs;* and, as regards the Carnforth boulders, the form and position of the limestone hills from which they came corroborate this conclusion. The same drifts reappear on the other side of Morecambe Bay, run up to altitudes of nearly 800 feet in Furness, and I have traced them thinning out along the slopes of the Coniston fells (see *Excursions from Coniston*). The drifts of England and Wales, which are unquestionably marine, afford a *measure of denudation* equal to the excavation of many a cove, the widening of many a narrow land-valley into a bay, the wearing back of many a slope into a line of cliffs, the modification of many a previously-existing escarpment, &c. It is not only the thickness of these drifts that must be taken into consideration. The extent of their horizontal distribution testifies to a denudation equal to the modelling of a great part of the present form of the ground. It could easily be shown that were these drifts to be replaced, they would be equivalent in bulk to the

* That *land*-ice in most parts of South Britain could not have supplied the sea with drift materials is evident not only from the position often occupied by drift-deposits, but from the smallness of the ancient valley glaciers rendering them inadequate to striate and smoothly-round stones and boulders. At least two stones out of three in the boulder clays of the north-west of England are striated and smoothed; but both Sir Charles Lyell and the late Principal Forbes agree that the existing glaciers of the Alps (in general very much longer than the ancient glaciers of South Britain) are only exceptionally capable of either striating or smoothly-rounding stones, though the rock-masses over which they pass are often striated, rounded, and polished by the coarse grit, sand, and fine mud which adhere to the bottom of a glacier, or intervene between it and its bed.

obliteration of many hundreds of miles of cliffs of average size, and the filling up of hundreds of cwms. Should it be asserted that the action of the glacial sea may have effected a general denudation of the land without leaving any striking new features, it may be answered that the tendency of sea-coast action is to produce cliffs with inlets, coves, and bays—in other words, to indent previously-existing land surfaces; and that, to enable it to make plains of denudation, a very slow and prolonged submergence is necessary. The general tendency of the action of rapid currents, in previously-existing valleys and passes, is to enlarge, not to obliterate them.

General Relation between Deposition and Denudation during the Glacial Submergence.—In considering drift as a measure of denudation, we ought never to overlook the truth of the following axioms:—'Deposition and denudation are processes inseparably connected;'* where the sea is not depositing it must be denuding; deposition can alone prevent denudation; on emerged land-surfaces, an area covered with coarse marine drift implies a contiguous area of denudation—with fine drift, either a contiguous or a distant area; on all land-surfaces where there are not superficial deposits, there must have been denudation; denudation may precede deposition in the same area during even a single submergence of the land.

Missing Drift Deposits.—In considering drift as a measure of denudation, we must likewise take into account, not only what remains in any particular locality, but what must have been carried to a greater or less distance. On this subject Mr. G. Maw observes: 'It must be remembered that the mere bulk of a drift deposit gives but slight evidence of the bulk of eroded strata from which it was derived. We have little

* Lyell's *Principles*, 10th ed. p. 107.

evidence to show the proportionate bulk which the gravels bear to the finely-triturated matter which would be carried away in watery suspension, or of the extent to which the gravel beds have been denuded after their first deposition; so that whilst, in the existence of drift between 200 and 300 feet thick, we have strong positive evidence of vast degradation of the older rocks, we see no limit to the extent to which that degradation took place during the deposition of the drift. *The more we look into the drift phenomena, the more convinced are we how very different the contour of the country must have been before the submergence of the land,* notwithstanding the probable existence of the present larger river valleys.' *

Measure of Denudation furnished by Angular Drift.—The most generally prevailing drift on the slopes of hilly countries consists of angular stones mixed with a greater or less quantity of loam or earth. On the summits and slopes of smoothly-rounded hills it fills up irregular hollows and grooves. In such situations it has probably been partly deposited by a great moving crust of land-ice previously to the great glacial submergence. It may graduate into, but is still distinct from, the moraines of district or valley glaciers.† I have not yet had an opportunity of tracing how far it corresponds to the 'trail' of the Rev. O. Fisher,‡ which he believes was formed during a second or supplementary glacial period. In many situations this angular drift, as long ago shown by Sir Roderick I. Murchison, would appear

* 'On the Drift Deposits of the Valley of the Severn.' *Quart. Journ. Geol. Soc.* January 20, 1864, pp. 141, 142.

† For remarks on the distinction between lower boulder clay, middle sand and gravel, upper drift, angular detritus, screes, and supra-glacial moraines, see *Excursions from Coniston.*

‡ *Geol. Mag.* vol. iii. and iv. and *Quart. Journ. Geol. Soc.* vol. xxii.

to have been driven forwards by violent currents of water, and to have accumulated where it was *arrested*.

The angular drift often lies in great quantities along the bases of hilly ridges, or in the recesses of valleys or cwms. I have devoted a considerable time to an examination of this drift, in Siluria and the west of England, and have satisfied myself, from a great number of instances, that it is not principally the effect of a disintegration *in situ*, but has been moved along from greater or less distances, though it is always very local in its derivation. A volume might be written on its distribution in Wales and the west of England. There is an enormous mass of it at the eastern base of the Malvern Hills. In the College grounds it extends to a great depth, and is so firmly compacted that it has been left standing as the roofs of drains. Under the Malvern Hills it has generally a smooth surface, and looks like a sea-beach. Eastward it becomes finer and thins out. I have traced it as far as Hanley Green. In the direction of Mill lane, it may be seen interwoven with the Keuper marls in a way that the action of waves or currents will alone explain. In the valleys of the Malverns, and in many Welsh valleys, it occurs under dry and loose screes, and does not seem to have merely fallen from above. That a great part of this angular drift is due to the action of waves and currents—the latter probably intensified or produced by *sudden* upheavals or depressions, as the land sank and rose during the glacial submergence—will, I think, be admitted by all who have particularly examined it. The action of coast-ice and icebergs would tend to increase the quantity of drift of this kind, either by carrying the débris of cliffs in a seaward direction, beyond the rounding action of waves; throwing débris up; or accumulating it in recesses beyond the reach of littoral attrition.* If we deduct from the angular drift of Wales and England, the portion which may have resulted from glacial and atmospheric action, I think a quantity will remain which cannot be accounted for without supposing a very considerable amount of marine denudation.†

* I have noticed that in the neighbonrhood of Garth Ferry, Bangor, the ordinary action of the waves detaches splinters and chips of the cleaved Cambrian strata, and heaps them up without being rounded.

† The theory of the non-submergence of the south of England during the glacial period is principally supported by the fact that in the country to the south of the Thames the superficial accumulations contain no trace of northern glacial drift. But the same remark applies to Wales, if we except the bases of the outside slopes of the hills of North Wales, and yet it is certain that a great part of Wales in which no trace of northern drift has been detected must have been deeply submerged. This, as Sir R. I. Murchison, the great authority on the subject, long ago showed, may have occurred during the earlier part of the glacial submergence, and before the relative positions of land and sea became favourablo to the passage of boulder-laden ice-floes in a southerly direction. The south of England may have been submerged about the same time as Wales, and before the ice-floes which strewed the midland counties with northern drift, or those ice-floes which dropped tho granitic boulders on tho Isle of Selsea, were detached from their parent glaciers in Scotland, the Lake District, Dartmoor, Cornwall, or Brittany. With regard to the south-west of England, the occurrence of fragments of Dartmoor granite mixed with rounded flint-gravel on the summit of Great Haldon, and the mixture of foreign elements with the rounded gravel of the Black Downs, clearly points to a submergence of nearly a thousand feet. Some regard this submergence as of early tertiary date, but Mr. Vicary, F.G.S., looks upon the gravels of the Haldons as of the same age with the 'head,' or detrital deposits with angular stones and boulders unconformably overlying the Bovey Lower Miocene formation. This head contains the remains of plants indicating arctic conditions. There are large boulders in many parts of Dartmoor which could scarcely have been transported from the parent rocks without the agency of icebergs. Mr. Maw (*Quart. Journ. Geol. Soc.* June 1864) draws attention to a bed of granitic detritus, at Petroclistow, 12 miles from the nearest Dartmoor granite *in situ*, which he believes may be of glacial age. I have seen numbers of blocks, called *Pudding-stones*, consisting of siliceous sandstone, often jasperized, with imbedded flints, scattered over many parts of the south-west of England, which look as much like boulders transported from a distance as any boulder-stones in the midland counties. They may be found in the Vale of Taunton, resting on lias and Keuper marl, between which and tertiary strata of their own age an immense thickness of rocks has probably been denuded. To suppose these pudding-stones

Duration of the Glacial Submergence.—Sir Charles Lyell is of opinion that the whole glacial period must have embraced, at least, several hundred thousand years. With regard to the duration of the submergence, if we suppose the subsidence and elevation of the land to have taken place at the rate of 2 feet in a century, the fall of North Wales to a depth of 2,300 feet, and upheaval to its present level, must have required 230,000 years. But making allowances for sudden oscillations over greater or less areas, varying from a few feet to say 50 feet, the average rate of subsidence and elevation would probably be as rapid as 4 feet in a century; which would give 115,000 years as the duration of the glacial submergence in North Wales, or the most instructive denudational area in South Britain. Mr. Ward ('Geol. Mag.' Jan. 1869) thinks that the rate of subsidence was slower than that of elevation.

Concluding Remarks on the amount of Denudation indicated by Drifts.—It is a growing opinion that certain drift deposits cannot be satisfactorily explained without supposing a submergence, after the second, or 'district,' subaërial glacial period, and before the submarine forest, or *Scrobicularia*-mud period. Mr. V. Searles Wood, jun., assigns a considerable depth to this post-glacial submergence. Whatever difference of opinion may exist relative to the necessity for invoking an extensive post-glacial submergence, I think the varied and complicated phenomena exhibited by the marine-glacial drifts cannot be well accounted for, except by supposing that a series of oscillations occurred during the great glacial submergence—in other words, that this submergence

to be mere vertical *downlettings* during the denudation, is to invest them with an almost miraculous power of persisting at different levels for millions of years, during the surrounding tear and wear of all the rocks that have been washed away.

did not consist of one uniform downward and upward movement, but of several submergences, and re-emergences, successively increasing in magnitude. If so, the amount of denudation may have been much greater than would have resulted from a regular depression and elevation of the land. These considerations are not, however, brought forward as arguments, but with the view of leading to further research.

PART IV.

CLASSIFICATION AND ORIGIN OF THE INLAND SCENERY OF ENGLAND AND WALES.

CHAPTER I.

CORRESPONDENCE BETWEEN SCENERY AND THE STRUCTURE OF ROCKS.

It has very often been remarked, that different kinds of rocks present peculiarities of surface-configuration; but this is only to a certain extent true, for the denuding agencies have acted on all kinds of rocks with so much uniformity as to leave effects of nearly the same character, chiefly differing in degree. The denudation has been influenced by the comparative hardness and softness of rocks, and the extent to which they have been disturbed by internal forces; but this remark applies more or less to all the great formations of the crust of the earth. Is there, then, no difference in the scenery of England and Wales arising from the nature of the subjacent rocks? The difference has mainly resulted from the softness of the rocks of certain districts preventing the perpetuation of rocky cliffs and projections, and by the horizontality, or small angle of inclination, of the strata in the same or other districts giving rise to a preponderance of flat, or nearly flat areas. All formations present the same types of scenery, but in the case of some the variations are more abrupt and the inequalities more crowded within certain areas than in others. Some formations combine scenery of the most opposite description.

To begin with the newer or softer deposits, even the boulder clay and drift accumulations in some places (though this may be best seen in Scotland and Ireland) are not without their heights, hollows, and escarpments. The tertiary strata have been shaped into escarpments, steep heights, and deep hollows, between Southampton and Hursley, in some parts of the New Forest, in Dorsetshire, in the neighbourhood of Bagshot, &c.; all on a small scale, it is true, but still mimicking the features of mountainous districts—bare rocky cliffs and projections excepted. The chalk presents many fine escarpments, cwms, and valleys, but certainly has this peculiarity, that nearly all the features of its scenery are more or less smoothed and rounded. The greensand generally presents a series of slightly inclined or horizontal table-lands bounded by escarpments. The Weald clay is generally very flat on the surface, some of the most dreary plains in England being found in the districts composed of it. The Hastings sand and sandstone rises into considerable hills in Sussex and Kent, and in the neighbourhood of Tunbridge Wells the scenery of this formation is rocky and picturesque. The oolitic districts include a great variety of scenery, partly but not altogether corresponding to the variations in its subordinate formations—scenery ranging from dull undulating plains, table-lands, and slopes, to abrupt rocky escarpments, deep valleys, and cwms. The lias presents a very different surface-configuration in different districts, being in some parts tame, as in Warwickshire, in others picturesque, as in north-east Yorkshire. The new red and Permian formations have been allowed to retain a flatness of surface-contour perhaps more than any other series of strata, but this has been mainly owing to their approximately horizontal position. The sandstones and shales of the coal-measures have in many places been denuded into very varied kinds of scenery. The scenery of the millstone grit, in Derbyshire, Yorkshire, and Lancashire, more than that of any other formation, consists of a succession of gently rising slopes, and very precipitous and continuous rocky escarpments. The mountain limestone, it has been remarked, presents a series of low rounded eminences, but with this characteristic we find combined more perpendicular and mural cliffs, and more abrupt rocky gorges, than are to be met with in any other formation of the crust of the earth. The scenery of the old red sandstone districts is often very diversified, and that on a scale of considerable magnificence, though, in England and Wales, the exposure of bare rocks at the surface is exceptional. It forms some of the finest mountains in the country. The Silurian formations of Wales and the Lake District present much more abrupt and magnificent scenery than any of the newer strata, but this is chiefly owing to the extent to which denudation has been influenced by the disturbed and highly inclined position of the rocks, to the great local difference in the composition of the latter, and, above all, to the resistance which has been offered by the hard interstratified or intruded volcanic rocks to the denudation which has removed the adjacent more vulnerable materials. The scenery of the granitic districts is perhaps more dependent on the structure of the rocks than that of stratified formations. It generally consists of rounded hills, with rocky projections at intervals, and (as on Dartmoor) crowning tors or bosses.

CHAPTER II.

RAISED SEA-BEACHES AND INLAND TERRACES.

On the shores of England and Wales it is impossible to trace an approximately continuous coast-line at a nearly uniform height above the present sea, such as we find surrounding a great part of Scotland. A coast-line at one time probably existed, but was elevated so long ago that the waves have had time to encroach upon it so as to wear it all away, except a few relics on the coasts of Devon, Cornwall, Somerset, &c.*

Raised Beach near Weston-super-Mare.—In the *Geol. Mag.* vol. iii. p. 115, Mr. E. C. H. Day describes the so-called raised beach at Birnbeck Cove, and gives a profile section. As this beach furnishes as typical a specimen as any which perhaps could be selected, and as it may in a few years be entirely destroyed by the waves, I subjoin an account of the succession of the beds from personal observation (order descending):—

Reddish loam, with angular and subangular stones, 4 feet;
Concretionary layers of sandstone, 2 feet;
Layer of nearly pure sand, 1 foot;
Conglomerate and breccia, consisting of rounded, angular, and subangular stones (with occasional flint chips), imbedded in an ochreous matrix, with sea-shells, and, in the upper part, bones. The stones sometimes lie loose, but in general are strongly cemented together.

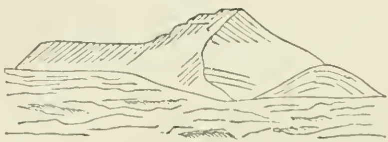
The last-mentioned bed is about 4 feet in thickness. It rests on the denuded edges of inclined strata of limestone, and a conformable thick bed of trap. Its base is

* I do not think that the shell-beds on the shores of Morecambe Bay (the age of which is probably intermediate between that of the upper boulder-clay, and a bluish-grey clay overlain by peat) can be regarded as representing the raised beaches of the south-west of England. Between Bardsea and Baycliff this shell-bed is as hard as rock.

from 25 to 30 feet above high-water mark. Behind this raised beach there is a limestone cliff which extends in a north-easterly direction. Its lower part is buried under angular detritus, which above the beach does not present the appearance of its having all fallen from the cliff, but rather looks as if it had been mainly deposited or thrown up during a sinking of the land.*

Terraces of the Liassic, Oolitic, and Cretaceous Districts.—On travelling from Weston-super-Mare by railway to Highbridge Junction, one is struck with the form of Brent Knoll, referred to by Mr. R. Chambers in his interesting work on sea-margins. The following is a very rough sketch of this knoll as it may be seen from Highbridge Junction (see Fig. 9). No one can

Fig. 9.



Brent Knoll.

doubt that the platform on the left, which is much higher than the raised beach near Weston, was once a sea-bottom, and that the steep escarpment underneath was a sea-cliff. The base of the latter is now very little, if at all, above the highest tide level. On the sides of Brent Knoll, both above and below the level of the platform, there are indications of small terraces. Some of the higher terraces may have been formed or modified in connection with the camp on the summit of the knoll. Those lower down (not represented in the sketch) look very much like indentations made by sea-waves at different tidal levels. To the north-east of

* See paper by author, *Quart. Journ. Geol. Soc.* vol. xxiv., Feb. 26, 1868.

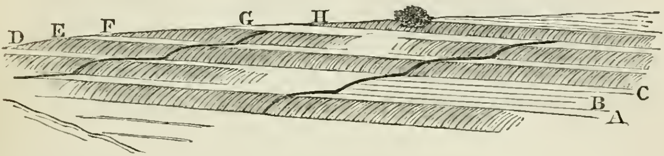
Glastonbury there are several very distinctly-marked terraces on the face of an escarpment, the base of which is very little elevated above the level of the sea. They are terraces of erosion, and could never have answered any human purpose. They are slightly waved, apparently in conformity with the outcropping strata. It is improbable that they ever marked a corresponding number of coast-lines. The action of a not very powerful sea, at different tidal levels, during a gradual rise of the land, offers a sufficient explanation, and one which can scarcely be rejected, considering that the sea must have been in their immediate neighbourhood at the period of the submergence during which the *Scrobicularia*-mud of the Somersetshire flats was deposited, and twice previously, as proved by the successive levels of the Weston raised beach and the Brent Knoll platform. In the district traversed by the railway between Glastonbury and Templecombe Junction, a geologist becomes bewildered amidst the thickly-crowded variety of denudational phenomena. Among them he can here and there discover single terraces and sets of terraces, nearly all corresponding to the outcrop of the strata, and therefore not artificial. Between Templecombe and Sherborne sets of terraces may be seen on the faces of escarpments, so sharply defined as to render it probable that they have been interfered with, if not partly formed, by man. That they are partly natural would appear from the fact that where they vanish the slopes retain a faintly scored appearance. Near Mere, several valleys are filled with small terraces. They are neither horizontal or parallel to one another, and the only certain conclusion that one can arrive at concerning them is, that they could never have subserved any human purpose. The valleys and slopes of the Dorsetshire chalk downs are grooved by numerous terraces more or less regular. In the neighbourhood of Bridport they are found running round detached hills of liassic and other strata. On travelling by railway from Salisbury to Warminster, an experienced eye can see traces of terraces on almost every hill-side, at various altitudes. In some places they are very sharply defined, but in most instances they only slightly project from the general declivity. They often merge, by insensible gradations, into the general contour of the ground. Here, and almost everywhere else among the chalk downs, a single terrace vanishes gradually at both ends, on a very gently as well as steeply-inclined slope, in a manner that could have never have facilitated the cultivation of the ground. These detached 'lynchets,' as they are locally called, vary from terraces of a few feet to escarpments of more than 100 feet in height. In the neighbourhood of Winchester terraces occur in considerable variety, and on the south slope of Portsdown, facing the sea, they differ very little in shape and size from the horizontal ridges left by the waves at different tidal levels on the steeply-sloping beach at Southsea.

*Terraces near Stockbridge.**—The most regular series of terraces I have yet seen in the chalk districts occurs on the side of a hill to the south-west of Stockbridge in Hampshire. The slope is so very gentle that one would suppose there could have been no inducement to break it up into terraces as a means of either facilitating cultivation, or reaping the products of cultivation. If these scarps were intended to divide strips of land belonging to different owners, the mode of separation must have required more labour, and been less effec-

* The very talented author of *Frost and Fire* has briefly noticed a set of terraces near Stockbridge which he regards as 'sea-work.' I am not quite sure of their identity with those described in this paragraph.

tual, than the present style of fence constructed of stakes and intertwisted boughs. They do not appear to have been embanked, or formed by the 'descent of silt,' and their general aspect, as represented in Fig. 10, would not seem to favour the idea of any kind of artificial origin. Platform A is about 60 yards broad, and

Fig. 10.

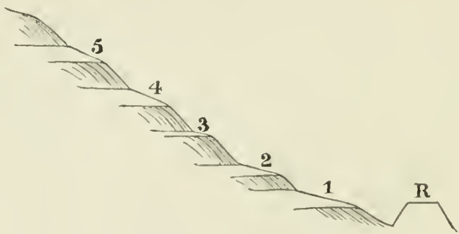


Terraces near Stockbridge.

considerably inclined transversely. Scarp B is about 12 feet high. Platform C is about 34 yards broad, and nearly level transversely. Scarp D is about 15 feet high. Platform E is about 64 yards broad, and very slightly inclined transversely. Scarp F is about 12 feet high. Platform G is nearly the same breadth as E, and very slightly inclined. Scarp H is about 8 feet high, and rather steep. The general steepness of the scarps is not above 20°. The above are the breadths where I measured them, but they are not the same throughout the length of the terraces. The latter incline longitudinally at a very low angle towards the north-east, or in a direction the *opposite* of the fall of the neighbouring river. On the left hand they curve round towards the west (beyond the limits of the engraving) in a manner showing that the river could never have had anything to do with their formation. In places they gradually vanish and reappear, and between platform A and scarp D one of them graduates into a series of smaller terraces, which can scarcely be distinguished on the spot. They are covered with a reddish loam, mixed with whole or fractured flints and a considerable proportion of extra-rounded flint pebbles. The lowest of them is at a considerable height above the flat and swampy bottom of the adjacent valley of the Test.

Terraces near Twyford.—The rounded and semi-rounded drifts and sandstone boulders between Southampton and Winchester occur at levels as high as the average height of a number of terraces which may be seen opposite Twyford on a very steep slope. In detail they are not quite horizontal, nor parallel to one another, but it is worthy of remark that the depressions on the

Fig. 11.



Profile of Terraces near Twyford.

Average height of scarps about 12 feet; Platform 3 is only two or three yards wide.*

platforms are generally under receding parts of the scarps. They appear to be almost entirely terraces of erosion, and the steepness of their platforms at once forbids the idea of their having been carved out for agricultural purposes. Unless we can conceive of our ancestors having been endowed with so great a taste for the picturesque as to dig out chalk for burning in a series of ornamental steps or shelves, I can see no agency

* The railway runs directly under the terraces. The fortunate proprietor of platform 3, on the theory of *severalty*, must have died rich!

likely to have formed these terraces excepting oceanic currents, or waves, at different levels, with or without floating ice; unless indeed we have recourse to the idea of a ponderous body of land-ice moving down the valley, and scooping out large grooves in the sides of the chalk hills. The general arrangement and form of the terraces is irreconcilable with the theory of fluviatile erosion at different levels.

Origin of the Terraces of the Chalk Downs.—It is highly probable, if not certain, that many of the more strongly-marked terraces with steep scarps and flat platforms were formed by man for purposes difficult to be understood, excepting where they may have been connected with camps. A number of the terraces, as ascertained by Mr. Codrington, F.G.S., and others, have a deposit of apparently made earth on their brows, but this of itself does not prove that man did anything further than increase the transverse flatness of their platforms. The platforms of natural terraces, where they were least easily obliterated, may formerly have been cultivated by farmers, and a continuance of the process would tend to steepen the scarps and flatten the platforms by removing earth from behind and accumulating it in front. Many terraces are still cultivated, but every farmer I have met with has assured me that there is now, and has been from time immemorial, a general desire to plough down the 'lynchets' (as they are locally called), and that formerly their number was much greater than at present. A large proportion of these terraces are *longitudinally* inclined to such a degree as to render the 'descent of silt' theory of their origin altogether untenable. Those very characteristics which at first seem to render it improbable that many of the terraces were once sea-margins tell with equal force against their having been formed by man. Their irregularity is often bewildering, and yet they graduate (as already stated) into the more general form of the ground, and, in most cases, conform in longitudinal inclination to the summit-contours of the slopes on which they occur, so as to suggest a natural rather than an artificial cause. I have met with no unprejudiced observer familiar with the forms, positions, and numbers of these terraces, who could bring himself to believe that all of them are works of art. The following arguments against artificial origin were written for this work by an eminent local antiquarian, Mr. Baigent, of Winchester:—'The theory that these terraces were made in the middle ages, and cultivated by different tenants, each of whom worked a particular terrace, is altogether fanciful. If so, how is it that we have no record of such a custom?—that none of those who have devoted years to the investigation and elucidation of the ancient rent rolls, manorial rolls, and ministers accounts, which set forth with minuteness the particulars of lands under cultivation—the crops that were grown, the rents payable, &c.—should have found no allusion to, or trace of such usage? These records extend in some instances as far back as 1199, and are continued down almost to our own times. They furnish ample evidence of the watchfulness maintained over manorial rights, and the fines inflicted for the slightest encroachment on the same. Had these terraces been cultivated by separate tenants and their successors, some rent must have been payable, and such tenants would have acquired the rights of copyholders, which they would have retained down to comparatively recent times, if not in some instances to the present day. Another fact must not be lost sight of, namely, that had these terraces been cultivated in the middle ages, they must have become tithable, and we should find them returned as such, or incidentally mentioned in the records of some of the very numerous disputes which occurred relative to tithes, and the compositions made between rectors, vicars, and conventual houses. Still further, if this theory be correct, is it not remarkable that in no part of the country has the separate cultivation of these terraces continued, or anyone laid claim to the above-mentioned rights? Lastly, the immense numbers of sheep grazed in the middle ages, and the consequent value of down land, must in a very great measure have prevented its being cultivated.'

Leaving Mr. Baigent in the hands of antiquarians, I proceed to remark that the terraces of the chalk downs resemble many of the smaller terraces in the north of Scotland and Wales, not merely where they are slightly horizontal and mutually parallel, but where they are slightly inclined and waved. A certain amount of inclination towards the head of a valley, and want of relative parallelism, has been most satisfactorily accounted for, on the principle of wave-action, by Mr. Darwin, in his *Geological Observations on South America.* An additional amount of inclination may, in many cases, be fairly referred to unequal upheaval or revulsional subsidence. A certain amount of waving may be explained by the action of waves conforming to waved stratification at intratidal levels, in the case of terraces of erosion. In the case of terraces of deposition, a certain amount of irregularity may be referred to the locally intensified action of waves at intratidal levels,* especially during a gradual fall or rise of the land. But it is, I think, by currents, acting on an easily-moulded material, that many of the terraces of the chalk downs can be most satisfactorily explained. On the shores of the Menai Strait, and the desiccated branch of it which

* I have seen many shingle terraces on sea-coasts dip more or less either towards the middle or towards both ends.

runs from Port Dinorwic to Bangor (see *Excursions from Bangor*), the slopes of marine drift are varied by small irregular terraces not distinguishable in form from those of many parts of the chalk districts.*

The shores of Morecambe Bay, from a few feet above the sea-level to at least 600 feet, are in many places marked by both terraces of deposition and erosion. Those which occur at high levels on ground which could never have been cultivated, as on the west side of Hampsfell, are chiefly terraces of erosion. In this district, as elsewhere, ridges have been artificially formed as boundaries between fields, but they are quite distinct from the terraces under consideration.

The vast majority of the above terraces, excepting where they are of considerable height, can only be well seen at a distance when under favourable light and shadow; and such being the case, it is difficult to conceive how they could have served the purpose of *boundaries* between narrow strips of land, unless among a race of farmers possessed of a degree of visual penetration corresponding to the great mental acumen manifested in the invention and construction of these terraces! †

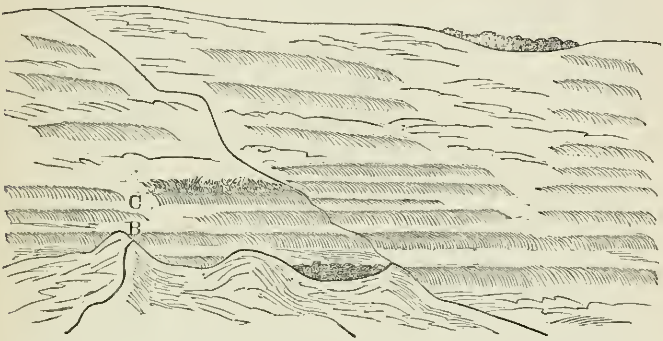
Terraces near Llangollen.—The finest series of undoubted old coast-lines or raised beaches I have yet met with may be seen diversifying the face of a hill to the south of Llantysilio railway station. The lowest of them, with the exception of a few traces on a cultivated field, cannot be at a less altitude than 1,000 feet above

* At the north-west end of the pass of Llanberis, the slope above Llyn Padarn and the Glyn slate-quarries is marked by a great number of terraces which, though very irregular and detached, exhibit a sufficient approach to horizontality to suggest wave-action. They *cross* the stratification and bedding of the Cambrian slates, grits, and quartz-porphyry.

† For a defence of the agricultural theory of the origin of terraces, in opposition to the author of this work, by G. Poulett Scrope, Esq., M.P., see *Geol. Mag.* July, 1866.

the level of the sea, and they extend, with more or less interruption, to an elevation of at least 1,500 feet. They happen to be well represented on the Ordnance map. The most perfect of these terraces, above Try-Carreg farm, are not now under cultivation, and the existence of removable trap boulders, and of ground more or less swampy, would seem to indicate that they have never been cultivated. A road-cutting, towards their eastern termination, reveals a section, consisting of a terrace of

Fig. 12.



Terraces near Llangollen, as seen from the hill north of Llantysilio Railway Station.

C B Principal Terraces.

erosion, covered by rounded stones imbedded in clay and earth. A small ravine has broken the longitudinal continuity of the terraces near Try-Carreg farm-house, and further to the west they have been separated on a larger scale by the brook which enters the Dee at Llantysilio station. As many as nine terraces can easily be made out on the slope above Try-Carreg farm, but they are resumed further to the west and south at higher levels. The scarps of the terraces (B C Fig. 12) are more or less rocky, and look as if they had been eroded backwards. The platform C is covered with fine clay and loam mixed with small stones, some of which are much rounded. Where the soil has been thrown up by moles, it appears mixed with the refuse of decayed shells, but I had not time to make a particular examination. The breadth of this platform is about 150 feet, and the height of the scarp underneath from 40 to 50 feet. Platform B is in some places swampy. (See accompanying engraving.) These terraces indicate pauses of considerable duration in the elevation of the land above the sea, and the transverse flatness of their platforms renders it probable, if not certain, that they were suddenly upheaved. Intermediate scarps occur here and there, which may have been left at different tidal levels, or may be the relics of scarps which in other places have been worn back into the main cliffs. The lower terraces deviate very little from longitudinal horizontality.

In many other parts of England, more or less decided traces of single terraces or sets of terraces may be seen, but they are apt to escape the notice of the tourist unless their scarps are in shadow. The wonder is not that such terraces should exist, but that their number should be so small; which, however, may be explained by the defacing action of the atmosphere, the shortness of the periods during which the land remained at stationary levels as it sank beneath or rose above the sea, and the absence in most areas of favourable conditions.

Relative Amount of Gradual and Sudden Upheaval.—The tendency of discovery has lately been to show the necessity for caution in attributing differences in the relative levels of land and sea to gradual elevation or depression. That the latter is a part of the economy of nature cannot be doubted, but it is equally certain that sudden risings or sinkings of the land are a common effect of earthquakes ; and if we are to judge of the past by the present order of nature, it would appear that a gradual rise or fall, with sudden movements at intervals, has been the mode in which the land has oscillated. Terraces with very sloping platforms and scarps may be explained by supposing a pause followed by a gradual elevation ; but I think the majority of the terraces of Wales indicate either an instantaneous vertical displacement, or an upward or downward movement of very brief duration. I venture to assert that in Wales there are terraces which can only be satisfactorily explained by supposing a sudden change of level amounting to 50 and even 100 feet. (See Sir R. I. Murchison's *Siluria*, 4th ed. pp. 490, 491, 496.)

CHAPTER III.

INLAND ESCARPMENTS, CWMS, CLIFFS, AND ROCKY PROJECTIONS—THE CRETACEOUS, OOLITIC, TRIASSIC, AND CARBONIFEROUS DISTRICTS.

Escarpments are terraces on a large scale, though, in England and Wales, we seldom find them in tiers one above another. They are generally bounded, either above or below, by approximately level ground. They differ from the ordinary declivities of hills in being *steep continuous* slopes, persisting for considerable and sometimes great distances. In a country where mountain peaks and serrated ridges are exceptional, escarpments form the most striking and imposing part of the scenery. The steep sides of narrow and deep valleys ought not to be included under the term escarpments. The latter are separated by wide areas, have plains, or comparatively flat ground stretching along, or away from, their bases. When found in valleys, the side opposite to the escarpment is either gently sloping, irregular, or comparatively depressed. They often, though not always, follow the lie of the strata. In most cases they either run along horizontal strata, horizontally along the strike or *upcrop* of inclined strata, or conform to the slope of inclined strata. Generally speaking, escarpments do not persist for great distances in crossing the stratification.

Supposing certain anticlinal ranges of escarpments to have been denuded before upheaval, it would, in their case, be more correct to say that the *strike followed the denudation* than that the denudation followed the strike. But it seems most probable that at least the majority of escarpments were formed after the strata were thrown into a more or less inclined position.

General Remarks on the Origin of Escarpments.—Two theories have been advanced to explain the conformity in the direction of escarpments to the stratification. One is, that escarpments have been formed by rain and frost, which are not sufficiently powerful to cross the stratification, but act on and follow the line of soft beds, by the decay of which the harder beds above are undermined. This theory will be fully discussed in the sequel. The other theory is, that all escarpments which conform to the stratification originated in fractures and faults, the direction of which the denuding agencies afterwards followed. I believe the theory of fracture will ultimately be found to be the true interpretation of the phenomenon. There are very few, if any, long lines of escarpment which follow the lie of the strata in *detail.* The coves and capes, bays and headlands, have partly been denuded obliquely to the stratification; and this fact is opposed to the very principle on which the atmospheric theory is founded. But a fracture, while it might mainly coincide with the strike of the strata, might be expected, from what we know of the windings of undenuded rents in limestone districts, to deviate laterally at intervals. The theory of fracture has therefore this advantage, that it accounts for the origin of bays and coves. In the case of an anticlinal upthrow, whether gradual or sudden, one might reasonably suppose the occurrence of longitudinal fractures, or at least lines of weakness which in their principal direction would follow the strike, while in detail the upcrop side would consist of a series of recesses and projections.

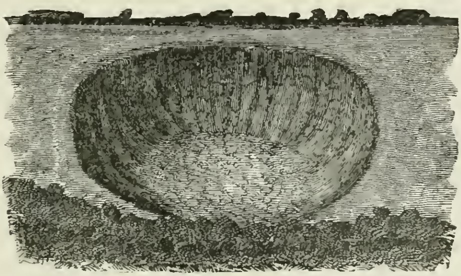
*Chalk and Greensand Escarpments of the Weald of Sussex and Kent.**—Supposing the chalk and underlying beds to have been longitudinally rent by several winding fractures during the elevation of the anticlinal axis, it is obvious that oceanic currents, or currents caused by submarine convulsions, would enlarge the fissures without deviating much from their course. On the inner side, where the strata would tend to slide along the slope, the currents (as can be seen in the case of wind acting on laminæ of blown sand) would mainly denude up the inclined planes of stratification. In this way the escarpments of the Weald may have been first formed. As the strata rose to a higher level so as to bring the bases of the escarpments within the reach of the waves, they may in many places have been undermined, or rendered more precipitous, whilst in others

* The tertiary escarpments of the Hampshire and London basins, though they do not form very striking scenery, are very instructive. In Hampshire especially their bases are generally level. In the neighbourhood of Southampton their identity with escarpments now in course of being formed by the sea cannot be mistaken. To the north and east of Romsey station there is an escarpment the summit and base of which are parallel lines. In the New Forest, and farther towards the west, there are some fine examples of tertiary escarpments, especially in the neighbourhood of Ringwood.

they may have been but little modified by wave-action, as we find on sea-coasts at the present day. It is not therefore necessary to suppose that the whole range, or even the greater part of the range of escarpments, was formed by sea-coast action. In many places, however, especially where the slope is steep and the ground beneath is a wide flat plain, the action of waves beating against a shore, and planing down a tidal zone, seems to offer the most satisfactory explanation. The absence of rounded flints is not a sufficient objection to the idea of temporary wave-action, for flints, as Sir Charles Lyell has shown, may fail to become rounded during two periods of submergence. The plains stretching along and away from the bases of many parts of the North and South Down escarpments are so flat (with the exception of a very gentle slope in one direction, which is a necessary result of an *excess* in the elevation of the land over the bed of the sea) that, on a scale of one inch to a mile, they are represented by straight lines. The escarpments themselves are in some parts straight and regular—as much so as on the sea-coast of Sussex at the present day. In most places they are indented by bays and coves. The latter in many, if not most instances, are not valleys, but curvilinear recesses, bounded all round by steep slopes—the innermost part of the slope being often the steepest. The coves are sometimes so geometrically curvilinear as to suggest the idea of having been literally whirled out by the eddy of a powerful current. Such hollows (their extreme smoothness and uniformity perhaps excepted) are likewise explicable by coast-action, as already shown. The coves or *cwms* (as I shall henceforth call them) are not confined to the escarpments. On the southern slopes of the South Downs they are sometimes to be met with, especially on the left-hand side of the highway from

Brighton to Lewes. About two and a-half miles from Chichester a very striking cwm, as large as the majority of the cwms of Wales, has been excavated in the smooth slope of a chalk hill. A chalk quarry (which it very much resembles in form) does not break the continuity of a slope more abruptly than does this cwm. It is called Kingley Bottom. On the western side the base of the cliffs is as flat as a part of a tidal zone. The surface of the cwm is covered with grass and yew trees; it contains no stream of water, and atmospheric agency seems to be doing less to denude its sides than the rabbits, whose burrows are here and there conspicuous. I did not think of measuring it, but it cannot be much less than a mile in average diameter.

Fig. 13.



Kingley Bottom, near Chichester. Sketched from Appledram Churchyard.

Subaërial Theory of the Denudation of the Weald.—Professor Jukes' theory of the origin of longitudinal valleys and tranverse gorges (which is a development of Colonel Greenwood's theory of soft valleys and hard gorges) has been adapted to the explanation of the Weald escarpments. The adaptation is based mainly on the fact, the significance of which was first pointed out by Professor Ramsay, that the escarpments mainly follow the strike of the strata; and partly on the alleged discovery that the River Medway, in the neighbourhood of Maidstone, has lowered its channel to a vertical extent of at least 300 feet, during the time that rains have been wearing back the neighbouring escarpments. The argument connected with the strike I have already considered. The theory that the Medway has excavated the transverse gorge of the North Downs through which it runs is founded on the fact that gravels composing terraces at a height of 300 feet above its level are of the same nature with the gravels now washed by the river. That the fact does not substantiate the theory will, I think, appear from the following considerations. (1) Extensive and continuous sheets or terraces of gravel cannot be accumulated by river-action. When a stream is rapid enough to transport stones, the latter accumulate at *intervals*, in the shape of heaps or ridges, on the sides or in the bed of the stream, and are not uniformly distributed over an extensive area.* (2) The existence of terraces of gravel generally implies a greater extension of the gravel transversely before the denuding or terracing down process commenced. In most of the valleys of England and Wales, the gravels must once have filled them up to a certain height, extending across in level lines, or sloping continuously down their sides. Such infillings of valleys can only be explained by the action of the sea.† The rivers of Devonshire are not credited by an eminent local authority, Mr. Pengelly, with having been able either to fill up or re-excavate their valleys. (3) In many parts of Wales, and throughout the north of England, the rivers have evidently formed their channels in the marine drift which often runs along their sides in level plateaux. (4) Allowing that the

* See *Mode and Extent of Fluviatile Deposition*, chap. xv.

† See *Marine Drifts*, chap. ii. part iii.

Medway is capable of re-excavating a valley, the identity of the gravels now washed by the river with those found 300 feet above its present level would only show that the river, instead of making gravel, is possibly playing with a marine drift which once filled up the sides of the valley, if not the whole valley, to the height of the highest terrace. (5) It is clear that the Medway cannot now (at least in many places) be manufacturing gravel out of rocks *in situ* of the same nature with the gravels at higher levels.* The theory of the excavation of the Medway gorge by the river is therefore really founded on the supposition that the gravels of the Weald district have been deposited by freshwater streams.† (See paper by Dr. Foster and Mr. Topley, on the Superficial Deposits of the Valley of the Medway, and Denudation of the Weald. 'Quart. Journ. Geo. Soc.' May 24, 1865.)

The mode of action assigned by Dr. Foster and Mr. Topley to rains and streams in the supposed formation of escarpments would never leave a form of surface free from ramifying valleys more or less V-shaped. As the widening of the valleys increased, their sides in time would reach an angle at which rain, in a state of dispersion, would be unable to check the growth of grass; and any farther levelling down through rain would be along the lines of its concentration in gulleys. The longitudinal stream could only widen as it deepened its channel, and it would practically lose its excavating

* In the neighbourhood of Maidstone, the gravel consists of subangular bits of flint and chert, with tertiary pebbles and pebbles of Wealden sandstone. Greywether fragments have likewise been found, the positions of which can only be explained according to the subaërial theory, by invoking a series of extreme improbabilities.

† The gravels of the Weald of Kent and Sussex occupy similar positions relatively to the configuration of the ground with the undoubted marine drifts of other districts.

Fig. 14.

Chalk Escarpment and Gault and Greensand Plain near Maidstone.

A Chalk. B Upper Greensand. C Gault. D Folkestone Beds (Lower Greensand.)

power before its channel became approximately horizontal. In other words, as long as any conceivable combination of streams acting mechanically on even the softest materials retained an excavating power, their channels could never merge into a surface approaching the flatness of the plains, which in many places lie near the base of the chalk as well as greensand escarpments.

Chalk Escarpments not Denuded conformably to Structure.—That the chalk escarpments must have been left by a cause capable of disregarding the denudability of beds, is evident from the annexed copy (Fig. 14, scale reduced) of a transverse section of the North Downs and Gault and Greensand plain near Maidstone.* In the 'Quart. Journ. Geol. Soc.' June 19, 1867, Mr. Searles V. Wood, jun., has given a section of the chalk and underlying gault at Royston, which shows that the scarp of the chalk 'is not due to atmospheric denudation, but to the erosion of a trough several miles wide, which is cut down *on*

* Dr. Foster and Mr. Topley, *Quart. Journ. Geol. Soc.* May 24, 1865.

both sides from the chalk and upper glacial clay into the gault.'*

Chalk Escarpments of Hants and Wilts.—Among the more regular escarpments of Hampshire is a steep, smooth, and nearly straight slope, to the north of Hursley, nearly level on the top and at the base, with no stream in its immediate neighbourhood. On the south side of the railway, between Romsey and Salisbury, there is a more extensive escarpment running for some miles to the west and east of Dean Station. Excepting a very slight longitudinal inclination, it is level and smooth at the base, and remarkably regular. Its straightness is only interrupted by a few very shallow cwms or concavities. It vanishes east of Dean Station and recommences farther on. Between Salisbury and Warminster, ridges and escarpments with longitudinally flat bases and summits may be seen presenting parallel lines one above the other. The great western escarpment of the 'Salisbury Plain' table-land, in the neighbourhood of Westbury, rises more or less directly from a plain, in many parts perfectly flat for considerable distances. It looks more like a sea-coast than any other chalk escarpment I have yet examined. It has evidently been formed by a process of forcible undermining, for the grass-covered line of cliff abruptly commences on the *side* of the gently-sloping edge of the table-land above, as if a previous continuation of this sloping edge had been worn back. The summit of the cliff varies in height.

* Though the softer beds which crop out in front of the chalk escarpments to the north and south of the London basin may have contributed to give a *general* direction to the denudation, we cannot examine an average transverse section without seeing that the escarpments could not have been formed by the wearing back of softer beds. Their slopes are at too low an angle, and the surface of the softer beds is too much a continuation of the general contour of the ground, to admit of such a supposition.

A number of very characteristic escarpments may be seen on both sides of the line of railway between Salisbury and Gillingham. The summit of the chalk escarpments is generally a line as straight as could be drawn with a ruler. The summit-lines of the inlying greensand escarpments are sometimes perfectly parallel to those of the chalk—a fact which no straining of the atmospheric theory will explain. In other places, where the summit-lines of the greensand escarpments are inclined planes, they are still too straight to be accounted for by subaërial denudation. We can scarcely evade the conclusion that the cause which planed down the top of the greensand escarpment on the south side of the railway must have acted on the base of the chalk escarpment beyond; and if this cause was the sea, the chalk escarpment, for a time at least, must have been a sea-coast. To describe all the more regular chalk escarpments of England would be incompatible with the limits of this work. I shall conclude with a reference to chalk cliffs mentioned by the Rev. O. Fisher, in the 'Geol. Mag.' vol. iii. p. 487, which I have not had an opportunity of seeing. They encircle cwms in the neighbourhood of Tisbury (Wilts), and are so steep that the chalk will not lie upon them, but disintegrates, forming a talus at their base. They may have been the beds of glaciers, as Mr. Fisher believes; but though ice may have enlarged them, it would be going very far to credit it with having accomplished the main part of the excavation of these cwms.

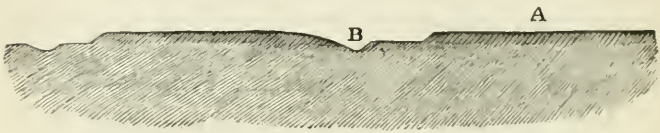
Greensand Escarpments.—In the Weald district the greensand escarpments are very irregular, arising from the locally varying hardness and softness of the beds. Leith Hill has often been noticed as surpassing the neighbouring chalk downs in the lofty and imposing front it presents to the level country (a country much too level to be explained by any form of linear or atmospheric denudation) which stretches away to the south. As seen from the neighbourhood of Horsham, it looks very much like an old sea-coast. In Dorsetshire the greensand presents a series of fine escarpments, among which may be noticed those bounding the table-land on which Shaftesbury is situated, with the outlying island-hill called Duncliff. In the south-west part of the county the escarpments of greensand and associated rocks are numerous. Their bases often graduate into smooth continuous slopes of rounded flint gravel, resembling tidal zones. Professor Ramsay speaks of escarpments in this district as follows: 'The same Atlantic, acting on the chalks and oolites, formed those abrupt escarpments stretching north and north-east from Lyme Regis, which in all but the want of water, even to an unaccustomed eye, present the semblance of a modern coast, with its bays, lochs, and outlying islands.'*

Greensand Escarpments of East Devon.—I have had several opportunities of examining the slopes of the Black Downs, which are crowned with abrupt escarpments. From the line of railway between Axminster and Exeter, they may be seen assuming a more or less terraced form. They surround the table-lands into which the great upland plain of the Black Downs is divided. As seen from the high ground north-east of Exeter, they present an unusually striking and regular aspect, arising partly from the whitened horizontal zones which mark the level of the sandstone, from which scythe-stones are quarried. The most extensive slope of the great greensand plain faces the vale of

* *Geological Survey Memoir on the Denudation of South Wales.* Professor Ramsay has since changed his opinions on many points, but he still refers a certain class of escarpments to the action of the sea.

Taunton. A considerable part of this slope is covered irregularly with a drift consisting of rounded pebbles and angular stones, associated with apparently re-deposited greensand and clay. The pebble beds are found more regularly distributed on the table-lands* above, which are immediately bounded by steep escarpments of greensand and chert. Fig. 15 is a representa-

Fig 15.



Northern Escarpments of the Black Downs (looking up).

tion of the northern slope of the Black Downs, as seen from the neighbourhood of Bradford (near Taunton). The steeply-scarped part of the slope A turns round into the shallow pass B, with the level of which its base-line corresponds. This pass graduates southwards into the upper part of the valley of the River Culm, and forms the watershed of a small stream, which runs down into the vale of Taunton. The channel of this stream, as one may perceive on the spot, has been superimposed on the northern part of the pass. The slope under the steeply-scarped part answers in every respect to a beach running down into a deep sea, and afterwards briefly exposed to wave-action during the rise of the land.

Great and Little Haldon may be regarded as outliers of the Black Down area. The escarpment of Great Haldon, facing Exeter, is in some places very steep, and though wonderfully level on the top, is often uneven at the base. Little Haldon has no regular escarpment, if

* See *Table-lands.*

we except the inner boundary of the cwm which forms the upper termination of Dawlish Valley. The hill is a ridge rounded off on the east and west sides, and horizontal from north to south. If the summit horizontal line be the result of marine denudation, the eastern slope for a considerable distance downwards presents a uniformity which must be referred to the same cause, during a gradual rise of the land. Great Haldon has a wider expanse of flat ground on its summit.

Traces of the Sea on and under the Haldons.—Mr. Godwin-Austen ('Trans. Geol. Soc.' vol. xi.) correctly describes the drift on the summit of Great Haldon as consisting principally of flints, but likewise, in places rather plentifully, of red porphyry, slate, granite, and quartz, having a very water-worn character, and rounded like marine shingle. The same remark applies to Little Haldon, though during my visit I missed finding granite or porphyry. On descending from Little Haldon towards Dawlish* the flints are found covering certain areas, while in others they are entirely absent, and the undisturbed trias comes right up to the surface. This would seem to be irreconcilable with the theory of the flints being mere downlettings during the subaërial denudation of a former overlying mass of chalk and greensand. But the manner in which the flints are arranged on the surface of the so-called triassic strata between the Haldons and the sea clearly indicates something more than atmospheric agency. To the south and north of Dawlish, where sections are exposed in road and railway cuttings, the flints may be seen interstratified with reassorted triassic pebbles, and sand sometimes obliquely laminated, not merely in hollows, where, according to Sir H. De la Beche, they may have

* Two trap boulders may be seen near a gate on the right hand, and on the sides of the Teignmouth road there are many erratic blocks of trap.

been washed in by rain-water. To the south of Dawlish they may be seen interwoven with rearranged trias on the summits of the east and west ridges, which cross the old Teignmouth road, and terminate on the sea-coast. On the south side of Dawlish Valley the flint drift lies unconformably to the slope, as if at one time it had been continued farther northwards, and afterwards denuded. To the north of Dawlish there is what has been called a raised beach, but there is no difference between it and the beds of flint drift farther inland, excepting that it extends for a considerable distance along the coast. The mixed flint and pebble drift of which it consists is overlain by a considerable thickness of sand. All this clearly points to the action of the sea, and if the ground under the Haldons and the level area on their summit are both more or less covered by marine drift, it is difficult to suppose that the escarpmented part of the hills could all along have escaped being a sea-coast.

Oolitic Escarpments.—The oolitic escarpments of North-East Yorkshire have been described by Mr. Topley, F.G.S., in the 'Geol. Mag.' (vol. iii. p. 435), and, along with the outlying hills, referred by him to subaërial agency. He partly founds his theory on the assumed incapacity of sea-coast action to follow the strike of the strata. I have already shown that escarpments may have been formed by the action of oceanic currents, supplemented by coast-action. But in North-East Yorkshire, as elsewhere, the escarpments do not everywhere follow the strike, especially in the so-called synclinal hills, the beds of which dip inwards on 'most sides' only. The high moorlands of North-East Yorkshire are bounded on the east and north by the sea, and on the west by the great plain of Yorkshire. This plain is covered with marine drift, and rarely rises more than 100 feet above the sea-level. The bases of the escarpments on the north and west of the moorland plateau, must therefore once, if not several times, have been in the neighbourhood of the sea. The marine drifts which occur in the east and other parts of Yorkshire, at much higher levels than the Vale of York, show that the sea must have washed the escarpments up to a considerable height; and why therefore deny that the cappings of inferior oolite were undermined by the sea? The cliffs on the western side of the Hamilton Hills are very imposing. They may be seen from the railway between Thirsk and Northallerton.

The Great Cotswold Escarpment.—One of the finest escarpments in England extends along the north-west boundary of the undulating Cotswold table-land from the headland of Nottingham Hill (south-east of Tewkesbury) to the neighbourhood of Cheltenham and Gloucester, and thence to Stonehouse. From Nottingham Hill it may be traced in an easterly direction as far as Northamptonshire. From Stonehouse, it runs in the direction of Bath. I have examined portions of it in the neighbourhood of Cheltenham, Gloucester, and Stonehouse. The summit (inferior oolite) is approximately level, and its base (lias) is a plain as level as any sea-bottom. There are two outlying island hills, Church Down Hill and Robin's Wood Hill, which may be seen from the railway between Cheltenham and Gloucester. Sir R. I. Murchison was the first to show that this escarpment must have acted as the south-eastern shore of the 'Straits of Malvern' during the time the sea covered the area intervening between the Bristol Channel and the Cheshire coast. It is not more certain that the sea is in its present bed than that its waves once washed this escarpment up to a considerable height. I have chiefly studied this escarpment between the two striking headlands which guard the entrance to the great bay called Whitcomb. This bay, like many on our present sea-coasts, embraces several coves or cwms which have been beautifully rounded out. The upper or more precipitous part of the escarpment is, in many places, very rocky; but a great part of it is buried under débris or screes. At some distance south-east from Crickley, in an inner cove, the grass-covered scarp on the edge of the table-land has obviously resulted from being undermined. There is a beach at its base consisting of detritus arranged in mounds, as if thrown up by a very tumultuous sea, or as if a sudden rise or depression of the land had occurred. On the south-west side of Crickley Hill there is a range of oolitic cliffs. They have been so much quarried as to render caution necessary in deciding on parts which have retained their natural form. In these parts the strata present the most obvious characteristics of an old sea-cliff. The face of the cliff is diversified by a series of longitudinal grooves, the smoothness and regularity of which contrast strongly with the effects of weathering. In the neighbourhood of the grooved and corniced surfaces the rocks, in many places, have been completely riddled with small holes. When I examined these holes, Mr. Pengelly's discovery of apparent lithodomous perforations in supra-marine limestone rocks had not been announced, so that I regarded them as the effects of the decay of the softer, or more fossiliferous parts of the strata, and such may still be their true explanation, though their proximity to sea-worn surfaces ought not to be overlooked. In Whitcomb Bay, generally speaking, the ground slopes away from the base of the oolitic cliffs, is covered with silt, and in other respects answers to what may have resulted from littoral marine action during a gradual fall or rise of the land.* The north and west sides of Leckhampton Hill, near Cheltenham, are very precipitous, but they have been so extensively quarried as to render it difficult to distinguish between natural and artificial cliffs. It seems likely that the Devil's Chimney is a natural sea-coast needle respected and left unscathed during quarrying operations, but this is far from being certain. On travelling by railway from Gloucester to Stonehouse, several fine cwms may be seen in the southerly continuation of the Cotswold escarpment. The south side of Stroud Valley is strikingly escarpmented, while its north side has a gradual and irregular slope. Between Stroud and Brimscomb there are several cwms, one of which is about the most curvilinear I have yet seen in South Britain. It presents the appearance of having been whirled out of the side of a regular, continuous, and level-topped escarpment. The power of sea-waves to excavate a curvilinear recess in a land-locked depression like the Stroud Valley may be doubted, but we ought to remember that though sea-coast action is greater in exposed than in sheltered situations, it is not altogether ineffectual in the latter. We ought

* Sir R. I. Murchison long ago observed that in the eastern part of the vale of Gloucester, fine local drift from the oolitic escarpment fills up depressions in the lias or is troughed in the gulleys of the lower slopes of the Cotswolds. Cheltenham partly stands on fine oolitic marine drift. Besides Sir R. I. Murchison, Professor Buckman and others have written on the Cotswold escarpment; and no one, I believe, has ever doubted that it has been a sea-coast. But as the Cotswold escarpment mainly follows the strike of the strata, subaërialists ought to be able to account for it by reference to atmospheric action, for their theory is chiefly based on the fact of *strike-following*. To the assertion that a depression may have existed where we now have the flat plain of Gloucester previously to the last encroachments of the sea on the Cotswold Hills, it may be replied that the advocate of marine denudation does not deny the existence of inequalities on the subsiding lands which from time to time become subjected to the action of currents and waves. The question here, as in the case of other escarpments, is, to what agency are we to refer the *escarpmental* form of ground? not the form of any slope or depression which may previously have existed.

likewise to take into consideration that where cwms occur in valleys, it is almost invariably on the steepest sides, and facing gently-sloping declivities or expanded areas which must have rendered them comparatively exposed to winds, or, at a lower level, to currents obliquely assailing them, and exerting considerable erosive power in the act of being deflected.*

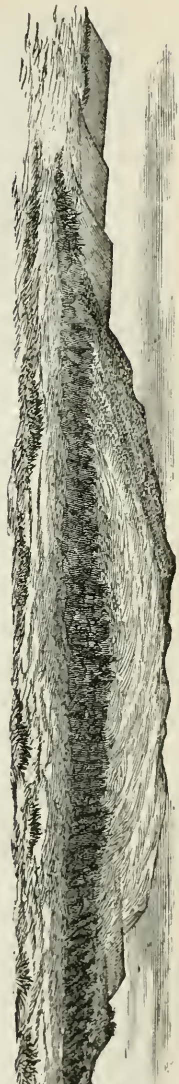
Bredon Hill.—In connection with the Cotswold escarpment, the outlying island, called Bredon Hill, ought not to be overlooked. The escarpment bounding its flat summit, especially on the northern side, is very steep and regular, apart from its modification by art. The Banbury stone, on the edge of this escarpment, and the 'King and Queen' lower down, cannot be satisfactorily explained in any other way than by regarding them as sea-coast rocks which have escaped atmospheric denudation.

Liassic Escarpments.—Among the most striking es-

* In a paper lately read before the Cotswold Naturalists' Club, Mr. Witchell believes that the combes of the Cotswold valleys were formed by the springs they contain. Before, however, the occurrence of springs in cwms can be regarded as furnishing any presumption that the cwms were excavated by them, the following questions must be considered. Do the springs along a line of escarpment occur generally at intervals such as might lead one to expect to find them in the parts which bend back into cwms? Is there sometimes more than one spring in a single cwm? Do springs in cwms occur on the sides, at the back, at the mouth, or in apparently accidental situations? I once saw a subterranean stream, not far from Crickley, flowing out of the side of a short V-shaped valley in such a way as to show that it could have had little to do with the excavation of the valley. Is it a fact that all the Cotswold cwms contain springs? On the supposition of a genealogical connection between springs and the Cotswold cwms, the dry cwms of the chalk districts could not have been formed by springs, for it is just as reasonable to believe that springs have broken out in cwms after their formation as that springs have disappeared from cwms. With regard to the supposition that the sea would not have selected the parts of escarpments containing springs to hollow them back into cwms, it may be remarked that these are the parts which would have yielded most readily to its undermining action, and the parts where coast-slips would have chiefly occurred. (See *Origin of Cwms*.)

carpments composed of liassic strata, may be noticed those bounding the low and level plains bordering on the Bristol Channel. In the neighbourhood of Glastonbury, on the south side of Polden Hill, and to the south-west of Langport, these escarpments must have been washed by the sea during the *Scrobicularia*-mud submergence, if not during historical times. The last-mentioned escarpment extends about six miles in a south-westerly direction, forming the south-eastern boundary of the marshy plain of Bridgewater, with its red marl island-like 'prominences.' It is continued as far as the northern front of the Blackdown table-land, the ground very gently rising along its base. On the right-hand side of the road leading from Taunton to Staple-Fitzpaine, there is a round outlying hill, completely detached from the escarpment. In the neighbourhood of Corfe, the liassic hills rise to a considerable height, and the escarpment assumes a cliff-like aspect on the side facing the vale of Taunton. Fig. 16 is a rough representation of the whole line of escarpment as seen from a rising ground in the neighbourhood of Blagdon.

Fig. 16.



Liassic Escarpments.

New Red Sandstone and Permian Escarpments.—Though these escarpments are in general less extensive than those of other formations, they frequently present abrupt, rocky, and picturesque cliffs, as in the neighbourhood of Bewdley * and Kinver in Worcestershire, and in many parts of Shropshire and Cheshire. From the great plain embracing the north of Shropshire, and the greater part of Cheshire, which was once the bed of the broadest part of the Severn or Murchisonian Sea, new red sandstone islands rise up here and there with cliffs and headlands. Among these may be mentioned Ness Cliff, Grinshill, the extraordinary assemblage of cliffs at Hawkestone (which will be particularly noticed in *Excursions*), and the cliffs of the Peckforton Hills. The main features of the latter, as may be seen from the railway between Beeston and Chester, consist of plains of marine denudation at successive levels, with bounding ranges of steep cliffs. There are some very regular Permian escarpments in Yorkshire, especially in the neighbourhood of Pontefract, and in other parts of the north of England. A short distance to the east of Wiveliscombe, in Somersetshire, the northern slope of a valley is crowned by a line of Permian sandstone (?) cliffs, with rounded caves, and other sea-coast characteristics.

Escarpments of the Coal-measures.—In most of our coal fields, escarpments are numerous, though most of them form the steeper sides of valleys instead of the boundaries of plains. In South Wales they may be seen cresting the slopes of valleys for considerable distances. In Monmouthshire and Glamorganshire, a series of parallel ridges, consisting of Pennant sandstone and lower coal-measures, separate the Rhymney, Tredegar, and Ebbw valleys. Their northern ends have been shaped into short escarpments, each embracing terraces, 'the re-

* See *Excursions.*

mains of ancient beaches.'* At the base of these escarpments there is a plateau of millstone grit, which gradually rises in a northerly direction.

Millstone-grit Escarpments, Cliffs, and Rocky Projections.—As regards the continuity of long bare rocky cliffs, the millstone grit is unsurpassed, excepting perhaps by the mountain limestone. One of the most perfect specimens, though on a small scale, may be found near Minera in Denbighshire, on the northern slope of the hill marked Pen-y-craig on the Ordnance map. It presents all the characteristics of a line of sea-cliffs. But it is in Yorkshire, North Staffordshire, and Derbyshire that the millstone grit crops out into the most imposing escarpments. Their general aspect cannot be better described than in the words of Mr. Hull ('Quart. Journ. Geol. Soc.' March 23, 1864): 'The millstone grit has a scenery of its own, marked by long lines of terraced or steeply-scarped hills, which contrast strongly with the undulating plain of Cheshire on the one hand, and the rounded outlines of the limestone hills on the other. We continually see the same form of outline, consisting of a gently-rising surface of moorland, broken off along a line of sharp cliff, as characteristic of the landscape of this formation. By these physical features the composition and arrangement of the strata are marked out with wonderful clearness. The summits of the ridges and escarpments being invariably composed of grit or sandstone, and the flanks of the hills and the valleys of shale; and as the steep face of the escarpment always tends to run in the line of strike, and looks in the direction opposite to the dip, the observer can often from some commanding point trace out the geological structure of the country around, by the aid of

* *Geol. Mag.* vol ii., April 1865. Article by Mr. Bevan, F.G.S., on the South Wales Coal Basin.

its surface-configuration alone.' In a denudational point of view, very little stress can be laid on the tendency of the millstone-grit escarpments to follow the strike, for the Kinder Scout grit of the escarpments on the east of the Saddleworth Anticlinal lies nearly horizontal. In the escarpments of the High Peak table-land, farther south, the strata in many places lie nearly horizontal.

The 'Third Grit,' according to Mr. Hull, forms the finest escarpments. They often run for miles in 'an unbroken wall of rock.' In the district of Shuntingslow, 'the third grit, lying nearly flat, stretches westwards, over a gently-rolling moor, and ends in a steeply-scarped cliff, below which the ground falls quickly away.' (Mr. A. H. Green, 'Quart. Journ. Geol. Soc.' March 23, 1864.)

Among the millstone-grit escarpments which present the most striking signs of having been washed by the sea, Stannage deserves to be particularly mentioned. It has 'every appearance of being an old sea-worn cliff; it has hollows or rock-pools in its face or on its summit; the escarpment is on the south-west side of the hill; on the other the slope is more gradual, and three or four terraces look very much like old beach-lines.' *

The Black Rocks of Stonnis near Cromford, show traces of the action of sea-waves, which a practised eye can easily distinguish from those produced by rain. Among these may be mentioned basins on the side of the cliffs, not merely due to the falling out of stones. The latter, however, are more common on Stanton Moor, a few miles to the north, where the cliffs are

* The Rev. J. M. Mello, *Geol. Mag.* vol. iv., Sept. 1867. Mr. Plant, of Manchester, lately discovered an old sea-beach on the limestone moors near Buxton, with smoothly-hollowed rock surfaces covered with loose shingle, and clay not derived from the limestone rock.—*Geol. Mag.* February 1867.

often crowned by rocky pillars resembling chimney tops. In various parts of Derbyshire the millstone grit has been shaped by the sea into pillars, locally called 'batches of old cakes,' which, though too hard to supply physical food to the geological tourist, may yet furnish a powerful stimulus to his imagination. The more compact kinds of millstone grit seem peculiarly adapted to resist weathering. The longer they are exposed to the atmosphere the harder they become—at least this is the opinion of quarrymen and masons. The Post-office and other houses in Cromford were built more than seventy years ago, and the marks of tools are now nearly as perfect and fresh-looking as when the stones were hewn.

'Sea-shore Rocks' of the Peak.—On the table-land of the Peak the millstone grit 'sometimes appears in little bosses, or it throws up groups of tabulated or fantastically-shaped stones, the forms of which I cannot but regard as the results of old marine denudation. In some places, especially near Edale Head, whole acres are covered with these groups or multitudinous assemblages of water-worn rocks. Among the various forms the table is common, but the smith's anvil appears to be a special favourite; nowhere else, so far as my acquaintance with these hills has extended, have I observed such numerous examples, in the same space, of sea-shore rocks.' (Hull.) *

Wharncliff Rocks, near Sheffield.—A few miles to the north-west of Sheffield, on the right hand side of the valley of the Don, one of the millstone grits (?) presents a series of cliffs consisting chiefly of blocks, the jointage-

* *Quart. Journ. Geol. Soc.* March 23, 1864. The escarpments around the peak table-land are as much sea-cliffs as any now in course of being formed. To try to explain away the traces of the sea they exhibit would be nearly as unreasonable as to regard fossils as mere sports of nature.

surfaces of which show few signs of disintegration. In connection with these cliffs may be noticed a long line of loose blocks, both angular and rounded, piled up and arranged similarly to what may be observed on the present sea-coasts of Caithness and Shetland, where blocks have been thrown up during storms.* Behind this moraine-looking accumulation, blocks more or less rounded may be seen scattered at irregular intervals.

Plumpton Rocks, near Harrogate.—These sandstone rocks have been classed by Sir Roderick I. Murchison as Lower Permian, and not without reason; but as they lie on the borders of a millstone-grit district, and present somewhat the same denudational phenomena, they are here introduced. They form a series of picturesque cliffs, which are rendered more so by their rising from the shore of an artificial lake. This circumstance likewise enhances the general resemblance they bear to sea-shore rocks. The more particular traces of marine denudation consist of narrow inlets left by the abstraction of whole blocks, rounded prominences and depressions, smooth-sided through-perforations in rocks, various effects of an undermining process, &c. A short distance south of the Plumpton Rocks, and to the west of Wetherby, I noticed a very extraordinary phenomenon in the shape of a perfectly detached stack of sandstone, covered on the top with grass, and surrounded by a green field, the mass of strata with which it was once laterally connected having been entirely removed. It presented no indication of being harder than the sandstone forming the surrounding site of the missing rocks. An agency circumdenudating it, and sparing it by accident, as the sea now acts towards rocks, seems the

* I first tried to account for this linear accumulation of stones by supposing it to be the remains of a stor[illegible], but soon saw reasons for rejecting the conclusion. I [illegible]ever, to leave its [illegible]in an open question.

only explanation which will include all the phenomena presented by this rocky islet. It has clearly been undermined all round. Rain and frost are now wasting its southern face, but they are producing a surface which strongly contrasts with the unweathered part of the rock. It is a perfect specimen of the combined decorated and plain style of marine architecture, consisting of arches, rounded caves with supporting pillars, perforations, &c., all smoothed or shaped with a regularity which nothing but the approximately geometrically-accurate sweep of eddying or gyrating waves or currents will satisfactorily explain.

CHAPTER IV.

INLAND ESCARPMENTS, CLIFFS, AND ROCKY PROJECTIONS *continued*—THE BRIMHAM ROCKS.

I HAVE seen no inland rocks in Great Britain which seem to point so unequivocally to the action of the sea as the Brimham Rocks, about nine miles from Harrogate. They fringe an eminence, or upheaved island, partly spared and partly wrecked by the sea. A group of picturesque columns may be seen on the eastern shore of this ancient island, but the grand assemblage of ruins occurs on the north-western side.* The geologist who would refer the varied shapes presented by these rocks to *weathering*, ought to be prepared to account for the line of cliff from which they ramify by invoking the same agency; and he ought likewise to be able to assign a reason why certain parts, chiefly connected with the coast-line of this eminence, should have been

* Though in one sense they are ruins, they are not the mere sports of nature, but the result of causes operating in accordance with dynamical laws.

selected by an agency (the atmosphere) to which the whole surface was exposed. The fact that the varying hardness and softness of the rocks renders them susceptible of being shaped by the atmosphere, is unavailable in the case of the Brimham Rocks, for among them *the rocks forming the sites of the removed rocks are often* as hard and undenudable as the remaining rocks which rise around these sites; and where variety occurs, the subaërialist would have a difficult task in showing a correspondence between the lines of variation and the direction of the denudation.

The Brimham Rocks not referable to Weathering.—A very brief survey will be sufficient to convince an unprejudiced observer that the Brimham Rocks, in many parts, have not been left by *granular dissolution*, but by *fragmentary* transportation. Their shapes are often made up of the original jointage-surfaces of the millstone grit. The passages separating the pillars have not, generally speaking, been left by the enlargement of the joints, but by the removal of blocks; and the blocks which remain must be regarded as the surviving representatives of the blocks which have been carried away *en masse*. As a rock-surface (and there are many such among the Brimham Rocks), not the result of a joint or fracture, must have been left by the removal of grains, so a rock-surface resulting from a joint or fracture must have been left by the removal of blocks formed by joints or fractures. At Brimham numerous blocks may be seen with angles nearly as sharp as when they were left *in situ*, or carried to their present positions, and the sides of many pillars, passages, or crevices reveal the jointage-surfaces of the rocks, nearly as fresh-looking as when they were first exposed. At the spot called the 'Kissing Chair' there is a very narrow winding passage quite open to the atmosphere, part of which has evidently resulted from the rock on the *coast* side falling slightly away from the other rock. We have no reason for supposing that this displacement occurred since the time when the neighbouring cliff was undermined by the sea, or disturbed by an agency which has been absent for thousands of years; and yet during all this time the weather has scarcely at all affected the rock-surfaces on each side of the passage, for the minutest hollow may be seen facing a corresponding projection.

Traces of Marine Denudation.—First, a line of cliff, above referred to, extending along the western and north-western part of the risen island of Brimham for more than half a mile. A detached part of this coast-line, behind Mrs. Weatherhead's farmhouse, shows a projecting arched rock with associated phenomena, which one familiar with sea-coast scenery could have no more hesitation in referring to wave-action than if he still beheld them whitened by the spray. Farther northwards the line of cliff in some places shows other characteristics of a modern sea-coast. Here an immense block of millstone grit has tumbled down through an undermining process—there a block seems ready to fall, but in that perilous position it would seem to have remained since the billows which failed to detach it retreated to a lower level. Along the base of the cliffs many blocks lie scattered far and near, and often occupy positions in reference to the cliffs and to each other which a power capable of transporting will alone explain. From the cliff-line passages ramify and graduate into the spaces separating the rocky pillars, which form the main attraction of this romantic spot.

Anvil, Mushroom, Table, and Tree-shaped Rocks.—These forms predominate among the rocky ruins of Brimham. They are frequently largest at the top and smallest underneath. Some of them, I think, show indications of their lower part having been eroded by the sea, after their upper part had risen above high-water level. A few of the pillars stand on very slender pedestals. The so-called Idol Rock, at least 20 feet high, and about 40 feet in circumference, rests on a pedestal, varying from about 3 to less than 2 feet in diameter. Had the waves proceeded a few inches farther, the superincumbent mass of rock must have fallen, and then the sea could not have left this striking monument to its denuding power. The right-hand side of the Idol Rock (see Fig. 17) would appear to have been

Fig. 17.

The Idol Rock, Brimham. Pulpit Rocks to the right.

directly assailed by the waves, which rounded it into a shape quite distinct from any of the effects of weathering to be found in the neighbourhood, while angular projections were left on the leeward side.

Rock-basins and Rocking-stones at Brimham.—Rain, assisted by detached fragments of quartz, may have excavated some of the rough and irregular basin-shaped cavities on the upper surfaces of the Brimham Rocks. But the curvilinear rock-basins cannot be thus explained.* These are to be found in various situations,

* See *Rock-basins of Dartmoor.*

and amongst others, underneath the rocks (the double rock-basin with a supporting pillar, called the 'Kissing Chair,' for instance), where the laterally and upwardly excavating action of the sea could alone have gained access. There are six or seven rocking-stones at Brimham. Most of them present every indication of their being nearly, if not exactly, *in situ*. At one time they must have formed a continuation of beds of millstone grit, of which they are now only the remains. The laterally-adjacent blocks would appear to have been carried away, and the line of bedding between the stone and the rock beneath must have been widened by the insinuating and erosive action of waves or currents, so as to leave it with a sufficiently slender support to admit of its being set in motion.

Perforated Rocks.—The Cannon Rocks, and others composing the great Brimham assemblage, present perforations of different forms and dimensions, some of them from 20 to 30 feet in length and transversely nearly circular. They are more frequently approximately horizontal than vertical, and can only be explained by studying the caprices and freaks of the sea on rocky coasts now under its dominion. It is probable, in the case of long perforations, that the part of the rock removed was softer than that now surrounding the cavity, and the missing part may possibly have been the infilling of a tidal gutter on the sea-shore previously to the consolidation of the millstone grit.

Concluding reflections on the Brimham Rocks.—As we gaze on this wonderful group of insular wrecks, varying in form from the solemn to the grotesque, and presenting now the same general outlines with which they rose above the sea, we can scarcely resist contrasting the permanence of the 'everlasting hills' with the evanescence of man. Generation after generation of the inhabitants of the valleys within sight of the eminence on which we stand, have sunk beneath the sod, and their descendants can still behold in these rocky pillars emblems of eternity compared with their own fleeting career; but fragile, and transient, compared with the great cycle of geological events. Though the Brimham Rocks may continue invulnerable to the elements for thousands of years, their time will come, and that time will be when, through another submergence of the land, the sea shall regain ascendancy of these monuments of its ancient sway, completing the work of denudation it has left half-finished.

There are many other cliffs, pillars, &c. of millstone grit in the West Riding of Yorkshire which cannot be here described. Some of them will be noticed in connection with mountain limestone escarpments.

CHAPTER V.

INLAND ESCARPMENTS, ETC. *continued*—MOUNTAIN LIMESTONE ESCARPMENTS—CLIFFS—CAVES, &c.

In the West and North Ridings of Yorkshire, and the neighbouring parts of Lancashire and Westmoreland, there are numerous escarpments, composed of millstone grit, Yoredale rocks, and mountain or carboniferous limestone. Ingleborough (2,361 feet above the sea) is capped by a slightly-inclined plateau of millstone grit many acres in extent, on the sides of which this rock forms an escarpment. Lower down there are ranges of escarpments consisting of Yoredale rocks and mountain limestone. These rocks likewise form escarpments on the sides of Penyghent and other hills. Some of the finest examples of mountain limestone escarpments may be seen near Clitheroe, Settle, Giggleswick, Clapham, Kirkby-Lonsdale, and in Wharfdale, and other valleys.* In Goredale ravine, there is an overhanging cliff said to be 240 feet in height.† Malham Cove is a remarkable semicircular cwm, surrounded by limestone cliffs, said to be 286 feet in height. Malham Tarn, the source of the River Aire, is above and beyond the cove. The stream speedily disappears and emerges at the base of the limestone cliffs. It is, however, evident that the action of the subterranean stream has had little to do with the formation of the cliffs or the excavation of the cove.

The direction of the escarpments of north-west Yorkshire and the neighbourhood would appear to have been at least partly determined by the Craven and Pennine faults. How far the escarpments coinciding in their direction with these faults may be due to denudation following fissures and rents, or soft beds faulted against hard rocks, would form an interesting subject for inquiry.

Mountain Limestone Escarpments of Westmoreland.—Among these, the lines of cliff in the neighbourhood of Kendal are among the most striking. South-west of the town there is a gradually rising and undulating table-land. At intervals there are rocky projections, and numbers of loose fragments, which have evidently been detached, drifted, and accumulated by an agency more forcible than any now operating on the spot. It is true the fragments are of local derivation, but it does not follow that they are *in situ*, while a particular examina-

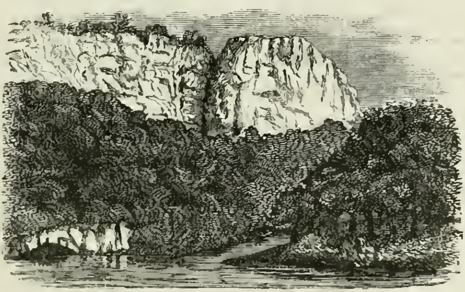
* In many places the above escarpments are pierced with caverns, which are either fissures enlarged by underground streams, or cavities hollowed out by an agency apparently directed inwards and upwards.

† Goredale is chiefly celebrated for its overhanging cliff and waterfall. Its cliffs, generally speaking, are not so high, nor on so magnificent a scale as the Cheddar Cliffs (see *Cheddar Cliffs*).

tion will show that they could not have been lifted up and placed in their present positions by any form of atmospheric action. The western termination of the table land is marked by what is locally called Scout Scar. It is a very typical specimen of a mountain limestone escarpment, consisting of a line of cliff with a talus. Farther to the south-west are the limestone escarpments of Whitbarrow, &c.

Mountain Limestone Escarpments of Derbyshire.—In Derbyshire, the limestone cliffs are chiefly found on one, and sometimes on both sides of a valley. In Dovedale the rocks can scarcely be included under the name of escarpments, but as picturesque cliffs they are perhaps unsurpassed in South Britain. In one part of the dale there is an arch with an adjacent cave, both of which show unequivocal signs of having been hollowed out by an agency distinct from river-action. In another place, at a lower level, there is a pillar which may possibly have been left by the action of the stream now flowing through this narrow valley. The greater part of the cliffs here and there present the appearance of having been at least modified by the waves, if not by the currents of the sea, during post-tertiary submergences. The stream has evidently only deepened its bed since the last rise of the land. In the neighbourhood of Buxton, and Bakewell, in the valley of the Wye, there are numerous limestone cliffs. From Old Matlock and Matlock Bridge to Willesley Castle, the eastern side of the deep valley of the Derwent, chiefly consists of mural cliffs, which in a great measure seem to defy the disintegrating power of the atmosphere. In some places there is a talus of stones more less or covered with grass, which does not now seem to be receiving much addition. Generally speaking, the bases of the cliffs appear to have been cleanly swept. This is especially the case with the very fine wall of rock opposite Willesley Castle, on the other side of the river, though it is possible a few fallen blocks may have been removed from its base by human agency. The cliffs facing Matlock Bath here and there present those *bracket-shaped projections* which are almost peculiar to limestone, and which not only indicate an undermining agency, but the upwardly-directed action of water. The celebrated High Tor rises to a height of about 400 feet above the level of the River Derwent, though scarcely half of the escarpment consists of bare rock. It forms the western termination of a plateau, on the other side of which there is an irregular escarpment of millstone grit. Near the middle of Fig. 18, a rent is represented, which runs

Fig. 18.



High Tor, Matlock.

for some distance behind the main part of the cliff. It has evidently been enlarged by water. Near the entrance, where lead-mining operations have not interfered with the natural features, the sides, and those parts of the roof which have not been rent asunder, exhibit rounded, smoothed, and hollowed surfaces, which cannot be explained by any kind of aqueous action not forcibly injected into the fissure so as to exert an erosive influence in an upward as well as lateral direction. The neighbouring configuration of the ground shows that a fresh water stream could not have flowed through this fissure without first running uphill. A gorge, traversed by the River Derwent, lies between the High Tor and Masson Hill. How far it may have originated in a fault or fracture, and how far marine and fluviatile denudation may relatively have been concerned in enlarging or modifying it, is a question not easily solved. That the sea sojourned in the deep valley of Matlock during the time or times the marine drifts of Derbyshire were accumulated is certain, and its currents could not have been idle in the narrow passages which here alternate with open areas. On the western or sloping side of the valley, behind Matlock Bath, there is a group of romantic pillars and detached masses of limestone rock which have apparently been left, not by granular dissolution, but by the bodily removal of large blocks. Behind Cromford Post-office (1865) there is a somewhat similar exhibition of semi-detached pillars and blocks. Between these rocks and Willesley Church there is a very singular narrow limestone ridge, the north side of which consists of the mural cliff facing Willesley Castle, already named. The south side is less precipitous, but still very rocky. There are some fine limestone cliffs, on the left-hand side of Via Gellia, a long winding gorge to the north-west of Cromford. It is traversed by an insignificant stream, and the tufaceous springs which issue from its side do more to fill it up than to excavate it. On walking from Cromford to Wirksworth, after passing a ridge, or col, near the Stonnis Black Rocks, a striking limestone escarpment may be seen on the right hand of the valley. In the neighbourhood of Wirksworth its cliffs are massive, and their bases pierced with caves.

Mountain Limestone Cliffs of Wales.—In the Llandudno peninsula there is no difference in form between the cliffs now washed by the waves and those at a higher level, or situated at some distance inland. Fig. 19 represents a groove (A) in solid limestone above the cliff-walk (B) Great Orme's Head; and Fig. 20 a groove the sea is now making near the base of the Little Orme's Head. The sea is likewise there excavating several caves with semidome-shaped or arched entrances. There is a large cave near the western end of the Head, which at the time I saw it was not accessible at mid-tide, but

Fig. 19.

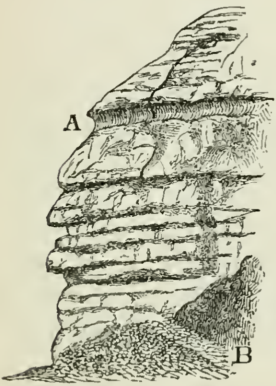
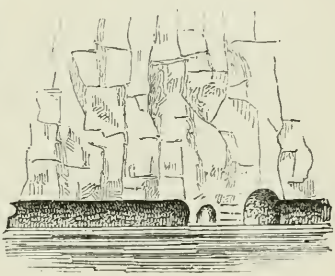


Fig. 20.



the waves made a great noise as they were grinding and smoothing its sides and roof by means of pebbles used as instruments of abrasion. On the escarpments of the Great Orme's Head numerous longitudinal grooves* and undercuts may be traced almost to the summit. The upheaved wave-worn cliffs are arranged in irregular

* 'On the fine inland cliff that overhangs the footpath on the west side, and north of the Gogarth Ruins, there is a remarkable concurrence of two lines of wave-hollow. One, still horizontal, and cutting right across the inclined lines of stratification, tells of a long pause in the upward movement of the Head.'—Mr. Darbishire. (*Mem. Lit. and Phil. Soc. Manchester*, vol. iv., 3rd series.)

terraces with intervening platforms or scars, and their resemblance to the Eglwyseg Cliffs near Llangollen, at a much higher level, is so great as to show that the latter must likewise have been shaped by the sea. At the entrance of the vale or rather plain of Clwyd, the bottom of which is covered with marine drift, the limestone cliffs on each side are as obviously sea-worn as any cliffs now washed by the sea.* Near Abergele there are several caves in the face of the wall of limestone rock, which may be distinctly seen on travelling by railway. One of them is a magnificent specimen of a sea-worn double cave, with a single arched entrance, and smoothly-rounded recesses and projections. On the face of the Cefn Cliffs, a few miles to the south, there are caves containing drift with sea-shells; and in one place I noticed an arched buttress partly choked up with drift. In the neighbourhood of Mold there are several striking limestone cliffs, and cliffs may be found at intervals in a southerly direction, until the carboniferous limestone formation in North Wales reaches its highest level and culminating escarpmental development in the truly magnificent tiers of cliffs called Eglwyseg or Eglwysegle. Fig. 21 shows only a part, and not the most imposing part, of these cliffs, as seen from the ridge between Llangollen and Glyn Ceriog, with Castle Dinas Bran in the foreground. There are

* In this part of Wales the transition from existing to old sea-margins can be distinctly traced. Between Holywell and Rhyl the coast-line gradually leaves the sea, and runs into the inland escarpment at Dyserth. Where the base-line is not level, it is still as obviously an old tidal zone as the part of it now covered by the sea is an existing tidal zone, and is only to be explained by unequal elevation. The idea of the sea having used rain-formed escarpments as coast-lines is here precluded, for on the opposite side of the vale of Clwyd, near Abergele, the limestone strata *dip* in the face of the line of cliffs unconformably to the base-line, clearly indicating a process of oblique or cross denudation which can only be referred to the action of the sea.

seven rounded promontories, with six intervening inlets. Of the latter, four are dry,* and two are traversed by small streams. Here and there the rocks are grooved by undercuts which must have been *ground out*, and are not merely vacant spaces from which fragments have tumbled down. Other signs of sea-action not so easily described are apparent on the faces of the cliffs. It would be going too far to say that the platform of each terrace marks a pause in the rising of the land, though the raised beaches of Try Carreg, on the opposite side

Fig. 21.

Eglwyseg Cliffs, near Llangollen.

of the vale of Llangollen (*see* Chapter ii.), show that the sea must have stood stationary at certain levels. There are limestone cliffs in the neighbourhood of Oswestry, the bases of which are pierced with caves. Farther south, the limestone escarpment of Llan-y-mynech Hill, which rises above a plain of fine marine shingle, presents sea-coast characteristics as striking as those found nearer the north coast of Wales. There is a limestone escarpment worthy of notice adjacent to

* At the time I write (July 1868), they are probably all quite dry.

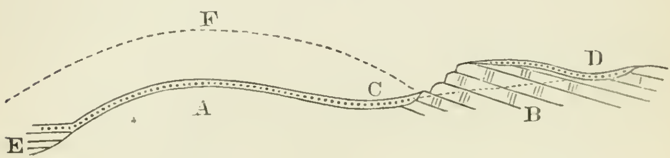
the Titterstone Clee Hill; but I must now proceed to describe those of Somersetshire.

Mountain Limestone Escarpments and Cliffs of Somersetshire.—For a considerable distance to the east and south of Clevedon there is an expanse of flat meadow-land which is continued as far as the neighbourhood of Wrington and Banwell. The greater part is still under the level of the highest tides. From the ridge on which old Clevedon Church stands, an escarpment runs in an ENE. direction behind Lower Clevedon, and, with the exception of the narrow gorge leading to Walton, it is continued for a great distance in the direction of Bristol. It forms the boundary of a part of the flat meadow-land which stretches to the base of the escarpment of Broadfield Down. For a considerable distance to the ENE. of Clevedon, I have traced a smooth uniform slope, like a desiccated tidal zone, which graduates into the meadow-land on one side and into the escarpment on the other. A similar slope may be seen in many places at the base of the Broadfield Down escarpment. The country between this escarpment-bounded area and the sea is very interesting. Beyond the NNW. bounding ridge lies the longitudinal valley of Walton (see *Longitudinal Valleys, &c.*), which is separated from the sea by another ridge, the inland side of which forms an escarpment with several cwms. Immediately behind Clevedon there is a line of cliff which is here and there rounded and smoothed in the usual sea-cliff fashion. It runs obliquely to the strike—in other words, crosses the lines of stratification. As we proceed farther south we find a more or less regular escarpment running nearly all round Weorle Hill. On the south side of this hill, a terrace, here and there interrupted by gulleys, runs along under the steeper part of the escarpment at a height of 30 or 40 feet above the level of the meadow-flat at its base. Brean Down, to the south of Weston Bay, may be regarded as the western termination of the Mendip range of hills. On its northern side there is the appearance of a raised beach; on the south side, the cliff is undistinguishable in form from many inland cliffs, and furnishes a fac-simile of several parts of the Cheddar Cliffs. The anticlinal up-throw of the Mendip Hills has lately been referred to the elevating agency of a mass of igneous rock by Mr. C. Moore, F.G.S.* Whatever theory of its origin we may adopt, it may be inferred that one or more longitudinal rents, or lines of weakness, would occur which would give a direction to the subsequent denudation. Though Mr. Moore opposes the idea that the summit of this anticlinal has undergone so great an amount of denudation as Professor Ramsay assigns, it must be admitted that a vast mass of strata has not only been shaved off the sides, but eaten out of the heart of the anticlinal. The out-cropping of the limestone on both sides of the old red nucleus forms a number of escarpments. One extends from Shuteshelve for several miles in an easterly direction. Its summit is an undulating table-land divided by the deep pass called Longbottom (see *Passes*). On this table-land, for a considerable distance, there is no general slope towards the south which could have originated a transverse stream necessary to set the longitudinal pluvial machinery going which, according to the subaërial theory, formed escarpments. The greater part of the angular stones beneath the above escarpment are mixed with a deposit of red loam which may have been derived from the decomposition of the old red, carboniferous, or new red sandstones. It is a part of the general covering of

* *Quart. Journ. Geol. Soc.* for December, 1867, vol. xxiii.

loam which may be found distributed over the Mendip Hills and the neighbourhood, irrespectively of the nature of the rocks underneath. Its relation to the escarpment may be seen from the transverse section, Fig. 22.

Fig. 22.



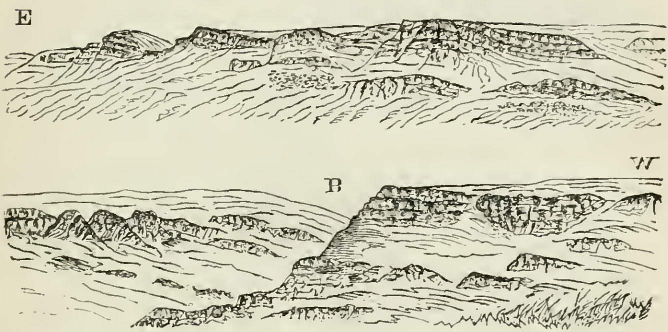
Section of Limestone Escarpment, Somersetshire.

A Old Red Sandstone. B Mountain Limestone and Limestone Shale. C Red loam and angular stones, the latter frequently mixed with rounded stones, especially on the table-land. D Longitudinal depression on table-land. E Sidcot Valley (Triassic dolomitized conglomerate). F Black-Down. C D Bottom of Dry Ravine.

Fig. 23 is a sketch of the escarpment, taken from the eminence to the south of Sidcot. Though its general direction mainly coincides with the strike, in many places it has been denuded obliquely to the stratification. The cliffs in a few places where they have resisted weathering, exhibit smoothly hollowed-out recesses. A short line of cliff nearly on a level with the highest or rocky part of this escarpment may be seen in Long-bottom Pass. Near Cheddar, on the south side of the Mendip Hills, there are several dry inlets the sides of which are escarpmented irrespectively of dip or strike.

The Cheddar Cliffs.—It is more in accordance with the structure and form of these cliffs to regard them as an escarpment than as the steepest side of a valley. It is true they rise out of a narrow defile, but in general they occupy the side which roughly follows the upcrop or strike of the strata. On the other side, in most places, the ground slopes down conformably to the dip of the strata nearly as far as the bottom of the defile. The probability is that the defile originated in a winding fracture, but it is very obvious that the fracture (at least in most places) was not sufficient to disturb the angle of inclination of the strata, which still corresponds on both sides.

Fig. 23.



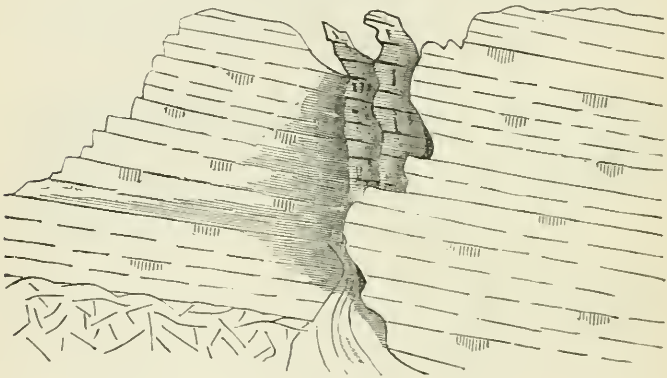
Principal part of an Upland Limestone Escarpment on the Mendip Hills, from beyond Longbottom Pass on the E. to near Shuteshelve Pass on the W.

B Dry inlet or ravine graduating into a shallow longitudinal pass behind.

It is equally evident that the supposed fracture could not have disencumbered the defile of the great mass of limestone rock which once must have filled up the now vacant space (the breadth of the fracture excepted). The end of the Cheddar defile which opens on the great marshy plain between the Mendips and Polden Hill is cwm-shaped. At a short distance from Cheddar the defile becomes very contracted. Beyond the highest part of the limestone ridge through which it passes, it opens out into a comparatively wide area with sides gently sloping and scarped at intervals.

This defile is therefore a pass open at both ends, and not a ravine on the side of a mountain. On the left hand (walking from Cheddar) or dip-side, there are cliffs here and there, but the grand display of mural precipices is on the strike-side or right hand. Some of the cliffs are bare, continuous faces of rock, perfectly perpendicular excepting where they overhang. The wall of rock, sometimes called the 'wind cliff,' cannot be less than 300 feet in height. As regards continuous perpendicularity and breadth, it is not perhaps to be

Fig. 24.



Section of the Cathedral Rocks, Cheddar.

matched in Great Britain, the Isle of Skye possibly excepted. In some places the cliffs project in columns, with vertical passages or 'rakes' between, as in the case of the so-called Cathedral Rocks (Fig. 24). The highest of these columns was measured by a gentleman of the neighbourhood a few years ago, and its projecting summit was found to be about 420 feet above the level of the road.

The Cheddar defile is very tortuous, and recesses on one side often face projections on the other; but the breadth and form of the gaps clearly show that their present sides could never have been in contact. In many places the recesses present the appearance of having been hollowed out by an agency, alternately deflected from one side to the other; and when all is still in the neighbouring plain, the wind sometimes blows violently in this deep and gloomy pass, and strikes first one side and then the other with a hollow sound which, to the contemplative geologist, might suggest the idea of audible though invisible spectres of tempest-roused billows which may once have followed the same course as they rebounded from cliff to cliff of a narrow inlet of the sea.

Origin of the Cheddar Cliffs.—In endeavouring to explain the origin of the Cheddar Cliffs, the merits of five theories may be briefly considered. Each of these theories would perhaps be benefited by supposing the previous existence of a winding fracture.

(1.) *Action of Rain.*—That the chemical action of rain-water has dissolved the limestone which is now missing in the Cheddar defile is inconsistent with at least two facts—first, the absence of any structural arrangement of strata which would lead rain-water to form an excavation of the particular form presented by the Cheddar defile; second, the mode in which rain now acts on the rocks, which is by washing down the loose parts of the cliffs in the shape of angular fragments, which continue angular, and accumulate where they are not removed by the hand of man—showing the incapacity of the chemical action of rain-water to dissolve them, and the inability of its mechanical action to remove them. In other words, rain is now throwing down the cliffs and filling up the Cheddar defile with their ruins—a process the opposite of forming the cliffs and excavating the defile.

(2.) *Action of Frost.*—Frost, by chipping off the overhanging, steeper, and less compact parts of the cliffs, and choking up the Cheddar defile, is likewise working in a direction the opposite of originating the phenomena requiring explanation.

(3.) *Unroofing of Caves.*—The chemical action of rain-water charged with *humus*, and percolating through the fissures of the limestone, would enlarge them, but on reaching a vacant space or cave communicating with the open air, this action would deposit stalactites which would rather tend to preserve than to destroy the roof of the cave, and stalagmites which would raise the level of the floor. The action of frost would be at its minimum in a cave subject to little change of temperature.* But supposing frost to act energetically, the bottom of the cave would be raised by débris as much as the roof would increase in height.

(4.) *The Action of a Subaërial Stream.*—To suppose the former presence of streams in all the dry valleys and passes of the mountain-limestone hills of Somersetshire, would imply an extent of watershed which could never possibly have existed in the district. But admitting the former existence of a subaërial stream in the area of the Cheddar defile, it must have flowed uphill before it commenced acting on the summit of the limestone ridge, unless we assign to rain a power of having washed out the open area behind, while the defile was in course of being excavated—an assumption at variance with the fact that a great part of the open area consists of rock similar to that forming the sides of the defile.† A subaërial stream could never have scooped out the caves which, at various levels, open abruptly into the defile at nearly right angles to its course. Neither could it have assumed so peculiarly

* See Mr. Pengelly's *British Association Report on Kent's Cavern*, 1865.
† See *Longitudinal Valleys and Transverse Gorges.*

tortuous a course as that of the Cheddar defile while it preserved sufficient inclination of channel to enable it to excavate; unless, indeed, it followed the windings of a rent, in which case it could not have acted upwardly so as to strip off the great mass of strata on the dip-side of the defile, in many places conformably to the angle of dip. But supposing a subaërial stream to be capable of having accomplished some of the above feats, while it flowed along a steeply-inclined channel, it must have lost the necessary degree of transporting and grinding power long before it reached so low an angle of inclination as that of many parts of the bottom of the Cheddar defile. But the principal reasons why the foregoing theories must be rejected will be found implied in the next paragraph.

(5.) *Action of Waves and Currents.*—The *Scrobicularia*-mud deposits of Somersetshire show that the sea, at a very late geological period, must have stood relatively to the land 30 or 40 feet higher than at present, and it is quite possible it may have reached a higher level. The existence of smoothed and perforated rock-surfaces (rock-work), on the Mendip Hills, and in some parts of the Cheddar defile itself, at a great altitude, show that the sea must previously have washed the Cheddar Cliffs; but we have no evidence of a subaërial or subterranean river having ever been on the spot, with the exception of the stream which now debouches near the mouth of the Cheddar defile. The sea will explain the general form of the Cheddar Cliffs better than any other known agency, and there are particular phenomena which no other known agency will explain: (1.) The immense mass of rock evidently stripped off, so as to leave mural precipices on one side and gradual slopes on the other. (2.) The existence in many places of unweathered joint-age surfaces, showing that the blocks once adjacent were carried away *en masse*, for a process of gradual dissolution would have more or less affected the remaining rocks as well as those now missing. The form of the unscathed faces of rock shows the form of the now missing rocks, at least up to the time of their removal.* In the case of a cheese, a Cheddar farmer would have little hesitation in swearing before a jury whether it had been cut by a thief with a knife, or nibbled away by a mouse, the only evidence being the *form* of the part left behind. (3.) The caves in the faces of the cliffs. Beneath some of these caves the cliff runs continuously along, and their mouths exhibit other proofs that no stream of water *flowing out* could have excavated them. Their floors are often flat, and their roofs arched. Not only their sides, but their roofs, present pot-shaped cavities which could only have been *ground* out by an upwardly-directed verticose agency, such as sea-waves. A large cave on the left-hand side walking from Cheddar occurs at a considerable height in the face of a cliff. Its floor is nearly on a level with a narrow terrace which, in the direction of Cheddar, graduates into a longitudinal concavity or wide groove, as if the level of the sea (relatively to the land) had for a long time remained stationary while the cave was in course of being excavated. The roof of this cave is smoothed and rounded. (4.) The undercuts at the base of the cliffs and at different levels, in the shape of cavities with flat roofs more or less smoothed, present indications of their having been formed by water injected with sufficient force to cause a refluxion capable of sweeping back the detritus in some instances uphill. (5.) The occurrence of smooth

* The bases of many of the cliffs, where screes have not fallen, appear as if they have been swept clean, and their faces are so smooth and regular as to show that they have never been subjected to any process of chemical dissolution.

semi-cylindrical grooves which graduate into undercuts on the one hand and into caves on the other, would seem to point to wave-action as the only admissible explanation. The narrowness of the Cheddar defile furnishes no reason for assuming that it may not have been subjected to the action of violent waves caused by

Fig. 25.

Typical Scenery of the Cheddar Cliffs.

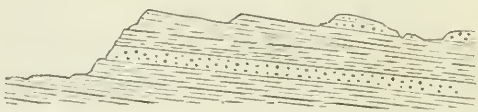
impetuous tidal currents, or transmitted from the open sea in the immediate neighbourhood; for the form of this defile is more allied to a strait than to a creek.

In addition to those described, there are mountain-limestone cliffs which might come under the denomination of escarpments on the banks of the Wye (see

Transverse Gorges), in Monmouthshire, on the northern border of Dartmoor, in Northumberland, &c.; and the Devonian limestone presents escarpments to the north of Ashburton, to the west of Kings Kerswell,* near St. Mary Church, in the neighbourhood of Yealmpton, &c.

Old Red Sandstone Escarpments.—They may be seen in the neighbourhood of Ludlow, the south east of Leominster, between Leominster and Hereford, at intervals all around Hereford, in the neighbourhood of Abergavenny, &c. One of the most magnificent, continuous, and regular escarpments in Great Britain surrounds a great part of the table-land (see *Table-lands*) called the Black Mountain, which lies between the irregular plain of Herefordshire and the low ground surrounding the lake called Llyn Safaddu, near Tal-y-Llyn, in Breconshire.

Fig. 26.



Section of North-west Escarpment of the Black Mountain (see the long section in Sir R. I. Murchison's 'Siluria').

On the ENE. side, this escarpment looks very imposing, especially when viewed from a considerable distance. It is partly covered with grass, and at intervals striped horizontally with bare strata of old red sandstone. But it is on the NW. side that this escarpment most strikes the observer (*see* Fig 26). It slopes sheer down in many places at an angle of 60°

* Between Kings Kerswell and Stoney Combe, the limestone forms a typical specimen of a level-topped escarpment.

† To the south of Abergavenny, in the face of the escarpmental outcrop of the South Wales coal-field, there are several fine cwms. One of them, in old red sandstone, called the Punchbowl, is very perfect; another, called Craig-y Cwm, has been partly scooped out in mountain limestone.

from the level table-land, which on this side is not broken up by gulleys, the drainage being towards the SSE. Its height cannot be much less than 1,000 feet. It is covered with verdure of the most brilliant hue, and is exceedingly smooth and continuous. There are several shallow cwms the curvilinear sides of which are disfigured by small black rain-ruts which have evidently never had a share in the formation of the escarpment. In Breconshire, the range of hills called the Beacons or Vans rise to a height of nearly 2,900 feet above the sea. On the northern side there are several fine escarpments * and a number of deep cwms. When viewed from certain points the summits of the ridges present a series of perfectly straight, and nearly horizontal lines, terminating in steeply-inclined lines, showing that the escarpments and cwms must have been denuded out of a table-land, or rather several table-lands rising above each other in extensive plateaux.† As seen from the eminence immediately to the south of Brecon, the hills appear sharply peaked at an average angle of between 40° and 50° (Fig. 27). The extensive range of mountains with steep escarpments which begins to the SW. of the Beacons, and runs through a great part of Breconshire and Carmarthenshire, likewise consists of old red sandstone. From certain distant points of view their

* In speaking of the above escarpments, Sir R. I. Murchison says: 'The grandest exhibitions of the old red sandstone in England and Wales appear in the escarpments of the Black Mountain of Herefordshire and in those of the loftiest mountains of South Wales—the Fans of Brecon and Carmarthen, the one 2,860, the other 2,590 feet above the sea . . . In no other tract of the world visited by me have I seen such a mass of red rocks (estimated at a thickness of not less than 10,000 feet) so clearly intercalated between the Silurian and the Carboniferous strata.'—*Siluria*, 4th edition, pp. 243, 244.

† I was more impressed with the first glimpse of the Brecon Beacons from a railway-carriage window at Three Cocks Junction than I have been with any mountain in Wales. Their outline excited a very unusual idea of sublimity.

summits present a horizontal line terminated by a very steep slope (from 50° to 70°) of great height.* Professor Ramsay, in his beautifully written and plausibly reasoned paper on the denudation of South Wales ('Memoirs of the Geological Survey,' vol. i.) speaks of these mountains as having been a sea-shore of the ancient Atlantic. Whatever opinions he may now entertain on this subject, all geologists are greatly indebted to him for having been the first to demonstrate that the old red sandstone area of South Wales, and the adjacent part of England, has undergone a denudation to which the term stupendous

Fig. 27.

Outline of the Brecon Beacons.

may appropriately be applied. Few conclusions in geology seem to be better established than that the summits of the Carmarthenshire and Breconshire Black Mountains, the Breconshire Beacons, the Blorenge Mountain (near Abergavenny) Pen Cerreg Calch† (on the opposite side of the valley of the Usk), the Black Mountain (on the borders of Herefordshire), and the tops of the

* On the north side of these mountains there are two small lakes. The most easterly, called Llyn-y-fan-fawr, lies under a remarkably straight and steep escarpment. The other, called Llyn-y-fan-fach, is situated in a fine cwm, with a very precipitous concave wall of old red sandstone. It is popularly asserted that there is a subterranean communication between this lake and Carmarthen Bay.

† Pen Cerreg Calch, the summit of which consists of a patch of mountain limestone, surmounted by millstone grit, is escarpmented and terraced nearly all round. There is a broad shallow concavity, very like a part of a sea-coast, on its WSW. side, and two fine cwms on its southern declivity.

Titterstone and Brown Clee Hills were once united, and that the depressions we now find between them, amounting in some places to a depth of at least 2,000 feet, are the effect of denudation.

CHAPTER VI.

INLAND ESCARPMENTS, ETC. *continued*—ESCARPMENTS, CWMS, AND CLIFFS OF THE SILURIAN ROCKS OF WALES AND THE WELSH BORDERS.

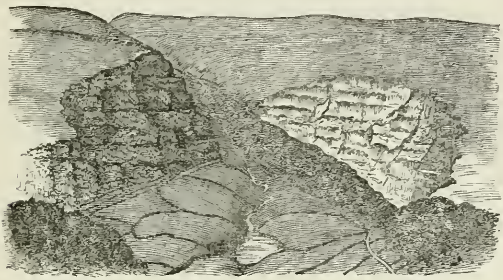
In the neighbourhood of Ludlow escarpments are numerous, and though most of them form the sides of valleys, many of them occur at sufficient heights above the channels of streams to preclude the idea of their being river-cliffs. One of the finest, with smooth, curvilinear cwms, may be seen on the right hand, on walking from Aymestry to Wigmore. It forms a part of the sides of the great Valley of Elevation so ably described by Sir R. I. Murchison.* The upper Ludlow Cliffs, at Abereddw, will be described in *Excursions around Builth.* The Wenlock limestone and shale forms some remarkable escarpments, among which Wenlock Edge, in Shropshire, must be particularly noticed. It is about the straightest, and at the same time longest escarpment in South Britain. It must have been a sea-cliff at the time the marine drifts of the neighbourhood were deposited. How far it may have been formed or only modified during the glacial submergence, it would be difficult to say. In one of its

* *Siluria*, fourth edition, pp. 124, 125, 126. See a reference to this valley under the head *Longitudinal Valleys*, &c.

caverns, called Ippeken's Cave, the remains of extinct mammalia have been found. Along the valley of the Severn there are several escarpments which cannot be regarded as river-cliffs. Where the river debouches into the great plain of Shropshire, the lofty cliffs of trap rock forming the northern termination of the Breidden Hills (see *Detached and Conical Hills*), not only seem to have been undermined and rendered precipitous by the sea, but it is certain from the great and uniform expanse of marine drift covering the flat plain at their base, that they must at one time have been washed by the waves. In the neighbourhood of Llangollen, the Wenlock shale forms several abrupt escarpments. Among them may be included the side of Barber's Hill, which exhibits a shallow concavity evidently cut out of the general declivity. On the right-hand side of Valle Crucis there is a steep and lofty escarpment covered with screes and wood (see *Longitudinal Valleys, &c.*). Behind Corwen there is a high and picturesque cliff of Lower Silurian rocks (of Bala age), named after Owen Glyndwr. The south-eastern side of the Berwyn ridge (Llandeilo and Bala strata with beds of volcanic ashes) is, in many places, finely scarped and hollowed out into cwms divided by buttresses. Llyn-llyn-caws, or Llyn-y-caws, is situated in one of the prettiest cwms in Wales. These mountains are often scarped so as to form terraces rising above each other, and occasionally encircling nearly whole eminences. Similar terraces may be seen among the Aran Mowddwy and Aran Benllyn mountains, and in many other parts of Wales. The eastern side of the Aran Mowddwy and Aran Benllyn range is steeply and almost continuously scarped, with irregularly-formed cwms at intervals.

Cliffs near Rhayadr.—Near Rhayadr, in central Wales, there is a discontinuous cwm apparently superimposed on a previous shallow valley, in which Gwyn Llyn is situated. The striking lines of cliff on both sides (Lower Llandovery Rocks) have apparently been worn back by sea-coast action.

Fig. 28.



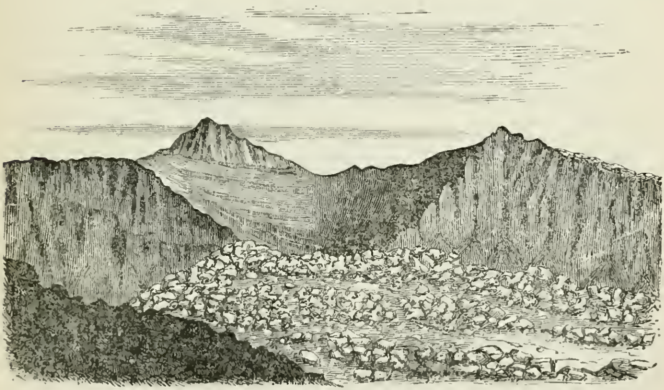
Gwyn Llyn Cwm, near Rhayadr.

Escarpments, Cwms, and Cliffs of Cader Idris.—It would be obviously incompatible with the limits of a work of this kind to notice all or nearly all the principal escarpments of Wales. Suffice it, in addition to what has already been stated, to describe those of the two most remarkable and best known mountains, namely Cader Idris and Snowdon. The escarpments and cliffs on the SE. side of Cader Idris are very rocky, magnificent, and varied in form; but I know of no wall of rock in South Britain which combines the characteristics of continuity, steepness, length, height, and bare rocky grandeur to so great an extent as the northern rampart of the mountain. The columnar character of the rocks likewise renders it peculiarly striking. It cannot be well seen from any part of the road between Barmouth and Dolgelly, while the view from the latter town is far from satisfactory. On ascending an eminence in the neighbourhood, it may be seen to less disadvantage. But it is from the high ground to the north of Llyn Guernan (on the right hand of the old Towyn road) that the most uninterrupted view of the principal part of this escarpment can be obtained. As the sun is setting in the north-west, the projecting parts of the cliffs often glow with a reddish-purple glare, while the indentations between them are plunged in bluish-purple shadows, which terminate in sharply-defined lines. The great rocky wall commences at a headland called Craig-cwm-uw on the Ordnance Map. It then curves round a very deep bay containing a llyn, on the eastern side of which its highest part is 2,043 feet above the level of the sea. Its farther extension northwards to the striking headland called Tyran Mawr, may be seen on looking up from the railway as you travel from the coast towards Dolgelly. Hitherto the rocky part of the escarpment, though very continuous, mainly crests a steep slope, more or less covered with débris, including enormous blocks. From Tyrau Mawr, for about a mile eastward, the whole escarpment is a slope with grass and rocks at intervals.* Then a wall of columnar blocks sets in, and is continued as far as the headland called the Saddle. Near the top of this wall the cliffs are divided into pillars, composed of one or more columns, on each side of which, and sometimes behind them, there are gloomy and inaccessible vacancies from which blocks have either tumbled down in recent times, or have been abstracted by the sea during the glacial submergence. The base of the great rocky wall is buried under débris, accumulated in ridge-shaped buttresses. Both above and below, there is a rugged waste of scattered columnar blocks (see *Excursions*).

* The usual ascent to the table-land of the mountain is made by zig-zaging this slope.

After passing the sharply-serrated headland of the Saddle (Cyfrwy), one of the most amphitheatrical cwms in Great Britain comes suddenly into view (Fig. 29). The inner concave precipice presents a succession of outcropping beds, consisting of columnar felspathic trap or porphyry, slate, greenstone, slate and felspathic ashes, surmounted (at the apex of the peak) by greenstone. The lower part of the cwm, and the whole of the basin-shaped part, has been excavated out of hard felspathic trap or porphyry. Here, then, no theory founded on a supposed process of undermining caused by the wasting backwards of soft strata, can apply. This cwm would appear to have been literally scooped

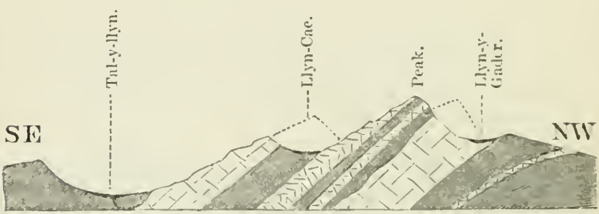
Fig. 29.



Cwm and Lake-Basin, Cader Idris.

out (as amphitheatres are now in course of being scooped out by the sea on the coast of Antrim) by the battering, detaching, and transporting action of waves, while the land remained at a stationary level, or was very slowly sinking or rising. Here none of the objections which may be advanced against the marine origin of cwms in dissimilar situations can apply. On each side of the cwm there is a line of cliffs, and on one side a headland. It is simply a concavity in a line of cliffs, in a highly-exposed position. The millions of blocks scattered towards the west, which graduate into, but in their origin are distinct from, the fallen débris of the cliffs, may be mainly regarded as the out-scoopings of this cwm. Ice, in the form of a great continental crust, a district glacier, an iceberg, or coast-ice, may have served to enlarge and deepen this cwm. Ice may likewise have left a part of the barrier of stones (as a moraine) through which the excess of water from the lake (Llyn-y-Gader) now percolates unseen; but the

Fig. 30.



Section of Cader Idris (reversed and reduced from the Geological Survey Sections).

1. Beds of Slate and Shale. 2 Felspathic Trap or Porphyry. 3. Slates with Felspathic Ashes. 4. Greenstone, more or less Amygdaloidal. 5. Felspathic Ashes with two bands of Slate. 6. Greenstone. 7. Slate. 8. Felspathic Trap or Porphyry, more or less Columnar. 9. Alternating beds of Felspathic and Calcareous Ashes, &c., and Slates (Llandeilo, underlaid by Tremadoc and Lingula Beds). The dotted lines represent Cyfrwy, or the Saddle, to the west of Llyn-y-Gader, and the steep cliff behind Llyn Cae or Cau. (Scale 1 inch to a mile.)

configuration of the adjacent ground would seem to forbid the idea that ice could have done anything more than precede, accompany, or supplement sea-waves in scooping out this semicircular hollow. From the appearance of the lake-basin, and the extent to which it is paved with stones, I think it more probable that the glacier which nestled in it merely jostled the previously loose blocks (the effect of the great excavating process) into the shape of a cauldron, and increased the height of the barrier by leaving a moraine, than that it *ground* out the cauldron (an achievement to which few glacialists would consider a small glacier equivalent in such a situation),* and left the enormous assemblage of blocks, which, were they to be thrown back into the cwm, would at least half fill it up (see *Origin of Cwms*). From Cwm-y-Gader † a very high wall of rocky cliffs extends in an easterly direction, in which the denudation has often crossed both the bedding and the cleavage of the rocks in such a way as to reveal its powerful and sweeping nature. Mynydd Moel (2,835 feet above the sea) forms the termination of this wall of rock, so far as it runs in a direct line; but beyond this headland there is a cwm with steep cliffs which gradually slope out and shallow off in a north-easterly direction. The whole length of the northern escarpment of Cader Idris, including the windings, is about ten miles, and it runs all this distance without a break or buttress. The average height of the eastern or principal part of the escarpment is probably about 900 feet. On the ESE. side of the peak of Cader Idris, there is the cwm containing Llyn Cae, or Cau, which forms the principal subject of Wilson's celebrated picture. This cwm in shape resembles an old-fashioned arm-chair with a peaked back. The back or innermost cliff (nearly 900 feet high) is the abrupt termination of Mynydd Pen

* The question of the pre-marine grinding out of lacustrine rock-basins by a great flow of land-ice will be noticed in the sequel.

† The height of the back cliff of Cwm-y-Gader immediately under the peak is nearly 1,100 feet.

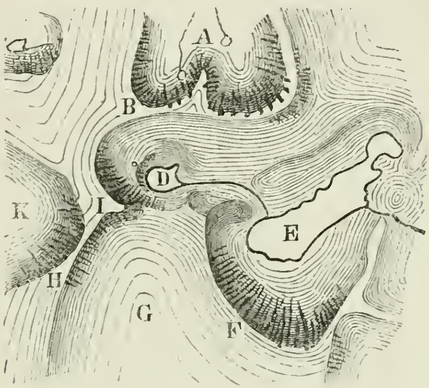
Coed. Its upper part is very nearly perpendicular, and commences so instantaneously on the gable-end of the ridge, that a person could with safety lie down and see the base of the cliff from its brink with his head projecting over. That Cwm Cae has been scooped out backwards, so as to leave the high and precipitous cliff just mentioned, seems obvious; but as this cliff has been denuded *obliquely* to the beds of slate, felspathic ashes, and felspathic trap of which it is composed, it must be referred to a cause capable of disregarding structure, and cutting right across rocks of different degrees of hardness; in other words, the action of the sea, or ice, or probably both, must be appealed to as furnishing the only adequate explanation of the excavation of Cwm Cae.

*Escarpments, Cliffs, and Cwms of Snowdon.**—The great eastern escarpment, which constitutes the principal feature of Snowdon, strictly so called, ranges from Yr Aran in a northerly direction to the narrow promontory or peak called Wyddfa, I. Continuing in a northerly direction, it forms the inner wall of Glas Llyn Cwm, D, and is resumed to the north of Crib-y-Ddysgyl (a ridge about 150 feet lower than Y Wyddfa), B, where it forms the western wall of Cwm Glas, A. There are several buttresses or ridges which branch off in an easterly direction. Between Crib-y-Ddysgyl and Y Wyddfa, the highest peak of Snowdon, there is one of the most magnificent specimens of a cwm in Great Britain. Its cliffs, on the north and north-east side of the peak, range from 1,000 to 1,500 feet in height, and are nearly perpendicular. Towards the base they consist of large masses of felspathic lava which would

* For a description of the scenery of Snowdon, see *Excursions*; and for a view of the mountain, see *Frontispiece*, Fig. 31.

seem to have withstood the action of the atmosphere to a very unusual extent. At the bottom of the cwm, and at some distance from the western boundary, is the nearly circular lake called Glas Llyn. Farther eastwards, and at a lower level, is the oblong cauldron-shaped cwm in which Llyn Llydaw, E, is situated. On the western side of the peak there is a large irregular

Fig. 32.



Map of Snowdon; the slopes longitudinally, and the cliffs transversely shaded.

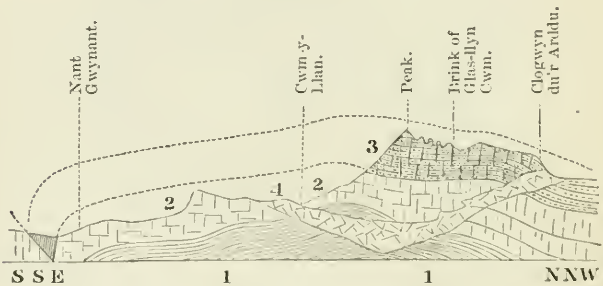
cwm (Cwm-y-Clogwyn, K) with a high rocky wall on the southern side, and on the east the narrow edge,* H, which separates it from Cwm-y-Llan, G. The western escarpment of Cwm-y-Llan is about two miles in length, and nearly straight.†

* This is the edge (Bwlch-y-main) concerning which Mr. Bingley made the erroneous statement, that two stones thrown down on each side would be a mile apart after each had hurled half a mile. This, of course, would take place on level ground. In some parts the eastern slope of the edge is about 60°, and the western 45°.

† The similarity of style or character between Snowdon and the western group of the Reeks of Killarney, embracing Carrane Tual, the highest of them, is very remarkable. Deep cwms separated by narrow edges mark

Denudation of Snowdon.—Fig. 33, from the Geological Survey section, has been *reversed*, so as to render it more readily understood by the majority of tourists who ascend Snowdon from the Llanberis or Capel Curig sides. This section at once shows that Snowdon is a mountain of denudation. The interstratified volcanic ashes and sedimentary beds, between 800 and 900 feet thick, which form the upper part of the mountain, have evidently been cut off by denudation, and the sudden commencement of the upper edge of the escarpment (which is here not nearly so steep as on the north-

Fig. 33.



Section of Snowdon (1 inch to the mile).

1. Llandeilo beds. 2. Felspathic Lava. 3. Caradoc or Bala beds with Felspathic Ashes. 4. Greenstone (intrusive). The dotted lines represent the extent of the denudation according to Professor Ramsay.

east side of the peak), would seem to point to an undermining process. No one can deny that directly degrading, or atmospheric agencies have had a share in

them both. Coomloughra Glen would answer to Cwm-y-Clogwyn ; Coomeenoughter, leading down into Hag's Glen, would answer to Glas Llyn ; and Curraghmore Glen to Cwm-y-Llan. [*The Rev. M. H. Close, in a letter to the Author.*] The correspondence is the more remarkable as the two districts differ in petrological structure. It furnishes a strong evidence that cwms were excavated by a cause capable of disregarding structure.—D. M.

wearing away the truly stupendous mass of strata, and the underlying igneous rocks, down to the level of Nant Gwynant. It would be going too far to assert that the eastern side of Snowdon may not have been a gradual slope before the undermining process which formed the cliffs commenced, whilst it is quite certain that ice in the shape of 'district glaciers'* must have modified the contour of the mountain, after the undermining process ceased. But ice, it is admitted by all, could only have modified the outline given by the great denudation. It could only have rendered the cliffs less steep, or in some cases more steep, according to circumstances, enlarged the cwms, and deepened or formed the lake-basins. What, then, was the cause of the great denudation which left the escarpments, cliffs, and cwms of Snowdon? Was it a current—not an estuarine tidal current, but a great oceanic river—either directly or obliquely assailing the mountain, as the Gulf and other streams now assail the submarine eminences and banks by which their courses are deflected? We cannot say how far currents may have been instrumental in forming, or at least, in giving a direction to escarpments, and in hollowing out cwms—currents either operating independently or following and preceding wave-action during a gradual depression and elevation of the land. Neither can we say how far 'waves of translation' caused by sudden upheavals or depressions of the bed of the sea, may have *torn out* and *swept away* the rock-masses and stony detritus by the abstraction of which cliffs and cwms were left, beetling and yawning, in the place of verdant slopes. So far as our actual knowledge extends, the cause most capable of forming cliffs, such as those of Snowdon, is

* A happy term used by the Rev. M. H. Close.

sea-waves. They would appear to be the most adequate to the task of undermining, battering down, and carrying away the blocks and fragments; the removal of which must, in a general way, have *kept pace* with the recession of the cliffs. It is not necessary to travel farther than the north and west coasts of Ireland to find mountains as far cut into by the sea as Snowdon has been undermined. If the Croaghaun Mountain, one side of which is a sea-cliff 2,192 feet high, in all probability becoming more and more concave, and the Slieve League Mountain, with its One Man's Pass, do not present features sufficiently resembling parts of Snowdon, I have no doubt there are other forms of sea-coast scenery, if not in Ireland, yet among the Feroe Islands, or in other parts of the world, which would furnish a satisfactory similitude, especially if due allowance were made for difference of petrological structure. The comparative absence of level beach-lines* at the base of Snowdon affords no presumption against ancient sea-coast action, as the bottom of the sea, under its present level, is in many regions very uneven, and as previously-formed level beaches may afterwards have been rendered uneven during a gradual rise of the land, by the action of waves and currents on rocks of unequal hardness. (See *Origin of Valleys*.)

Recent Atmospheric Action in Snowdonia.—Whatever may have been the cause of the removal of the mass of rock necessary to leave the escarpments and cliffs of Snowdon, it is difficult for an unbiassed observer, looking up from the vale of Nant Gwynant, to resist the impression that the cause is no longer in operation on the spot. It is true that the atmosphere has for ages been here busily at work, but its tendency has been to dilapidate,

* There *are* flat areas in front of the cliffs of Cwm du'r Arddu, of Cwm-y-Clogwyn, and of Cwm Llafar, &c. (see *Excursions*.)

and not to fashion. In this august temple of nature, it has acted in the same way as on temples made with hands. It has destroyed the details of a style of architecture which is still revealed by the general form of the escarpments. Subaërialists accuse the advocates of marine denudation with denying the power of the atmosphere to denude the earth's surface, but the latter merely dispute the capacity of rain and frost to give rise to certain forms of ground. Frost, rain, and streams have very great power in the Snowdonian district. They can not only be seen, but heard. The roar of the torrent often mingles with the crash of the falling block. There are indeed streams of stones as well as streams of water. But is it not obvious that all this tends to destroy, and not to produce, the real form of the ground? Are frost, rain, and streams not throwing down cliffs, filling up cwms, choking up passes, and excavating narrow gulleys on previously smooth surfaces? As long as we confine attention to the silent and imperceptible action of atmospheric agents, it is easy to suppose them capable of wearing back escarpments, and hollowing out cwms, and at the same time removing the disintegrated materials. But where, as in this district, their degrading and dilapidatory action is great, and their transporting agency not only comparatively small, but in many places next to nothing, it seems very unphilosophical to consider them equal to the performance of the whole, or even the main part, of the task of effective denudation.

The Pluvial Theory inapplicable to Snowdon.—Supposing rain to be capable of wearing back cliffs through the wasting away of underlying soft strata, accompanied by the removal of detritus, the mode usually assigned to its action would not account for the escarpments and cliffs of Snowdon, where the deviations from horizontality of outcrop are in many places sufficient to show that the denudation must have proceeded more or less obliquely to the strike. We likewise often find that the lower part of a cliff consists of hard igneous rock, and the upper of comparatively yielding strata. Should it be asserted that rain may have acted most readily on igneous rocks, so as to undermine the aqueous strata above, then the pluvial theory would fail in explaining those cliffs where igneous rocks are the uppermost, as in the case of the great cliff on the NE. side of Carnedd Dafydd, &c. In Cader Idris, the highest part of the peak consists principally of greenstone, while lower down there are alternating beds of columnar felspathic porphyry and slate. In the volcanic districts of Wales, where cliffs and cwms are the most frequent, the denudation has ignored the chemical composition, and to a considerable extent the structural arrangement of the rocks.

Were the Cwms of Snowdonia left by the tumbling out of Rocks?—Mr. Wynne ('Geol. Mag.' vol. iv. p. 5) suggests that rain-water finding its way downwards through joints, may tend to separate rock-masses, which 'where deprived of support by springs, streams, ice, or it may be in some cases even by sea-waves, naturally fall away, leaving vertical, or approximately vertical faces of rock behind.' But it is obvious that a repetition of this process would prevent vertical faces of rock from being left behind. The first series of undermined blocks might tumble down a slope leaving a cliff behind, and comparatively level ground in front of it; but a greater or less part of the second fall would remain on this level ground in the shape of a talus, which would limit the next fall to the upper part of the cliff, and so on until no visible cliff would remain—that is, unless there happened to be a power at hand, such as sea-waves, capable of carrying away the blocks, or dissolving them with a rapidity proportionate to the downfall. It has never been shown that rain and springs are possessed of this power, in other words, that they are possessed of a power of depriving, and continuing to deprive, rock-masses of support to nearly the extent necessary to explain the origin of cwms. On very steep slopes masses of rock have no doubt often tumbled out, leaving shallow depressions; but in these cases the missing blocks and fragments may generally be seen in situations to which they *could have fallen*. In the case of cwms, generally speaking, the missing rocks are either found scattered in neighbouring positions where they could never have fallen, or entering into the composition of widely-spread drifts. The theory of tumbling out presupposes a steep slope, and the question arises, How did this slope originate? Under many cwms there is a steep escarpment the summit of which graduates into the floors of the cwms, and this escarpment stands as much in need of explanation as the cwms themselves. Admitting that the missing rocks may have slidden down, is it not most reasonable to suppose that this took place while the escarpment was in course of being worn back—that this process of wearing back deprived the superjacent rocks of support, and that they were carried away before the process came to an end? In the case of many cwms with frontal declivities, however, the form of the floor, the dip of the strata, and other phenomena preclude the idea of a sliding forward of the rocks. In the case of others, frontal declivities or falling escarpments are not only absent, but the floor graduates into the neighbouring open country with so slight a slope as to show that a falling away or sliding along of rocks could have formed no part of the process by which they were excavated. The rocks missing from the area of

Glas Llyn Cwm or Cwm Llydaw could never have slipped all the way into Nant Gwynant; and in such flat-bottomed hollows as Cwm Llafar it is obvious that any process of downfalling has been to dilapidate the cliffs at their inner terminations, and not to form the cliffs.

Were the Cwms of Snowdonia formed by the Degrading Action of Rain?—If the undermining and retrogressive action of rain-water and its power of depriving rocks of support so as to allow them to slip, be inadequate to account for the principal phenomena connected with the cwms of Snowdon, its directly degrading action, will, I think, likewise be found to fail. The downward action of rain is most apparent on the *brinks* of steep slopes to which the superjacent ground is inclined. It tends to make the gently-inclined ground above to graduate into the ground below the slope by a series of ruts, as repre-

Fig. 34.

Fig. 35.

sented by the dotted line in Fig. 34; but it appears incapable of wearing back and at the same time preserving a cliff—especially a cliff from which the ground declines (Fig. 35), as in the case of the back slope of Glas Llyn Cwm, the top of which is a waterless boundary of two watersheds. Towards the base of the slope the concentrated action of rain-water produces ravines, instead of a uniformly curvilinear surface.*

Snowdon as seen from Cader Idris.—At the time (May

* For additional facts and considerations relative to this subject, see *Origin of Cwms*, and Excursions from Bangor and Llanberis to Snowdon, Nant Francon, and Carnedd Llewelyn.

1866) when I viewed Snowdon from the top of Cader Idris, it was covered with snow, which so increased the contrast between the illuminated or northern side of Glas Llyn Cwm and the side plunged in deep shadow, as to suggest very forcibly the power of the agency by which the eastern side of the mountain was indented, undermined, hollowed out, and worn back; and the idea arose that 'old ocean,' may have been sapping the foundations and scarping the peaks of both mountains at the same time.

The Cwms of Snowdon contemplated from a Moderate Distance.—It is quite certain that the sea must have washed the cwms of Snowdon during the glacial submergence.* These now silent recesses must then have echoed the thundering of the billows, as stone after stone of their encircling walls was battered down and swept away. For all that we know to the contrary, the highest peak of the mountain may once have been just visible above the froth and foam of conflicting breakers. A great change has come over this part of the earth's surface. An archipelago has become a group of hills. Sea-cliffs have become upland escarpments. But as the well-defined and level surface of the sea of mist, which often envelopes the base of these escarpments and stretches into their cwms, is contemplated, the idea of the spectre of a departed ocean does not appear too far-fetched. During violent gales, the wind still makes

* Professor Ramsay and others have discovered extensive deposits of marine drifts on the Snowdonian range of hills up to a height of at least 2,300 feet above the present sea-level, or to within 1,270 feet of the height of the apex of Snowdon. It follows that the sea in Cwm-y-Llan, on the SE. of the apex, must have attained a depth of nearly 700 feet at some period during the glacial submergence. At that time it must have been washing the floor of Glas Llyn cwm, and undermining the base of the great NE. wall of Y Wyddfa. Supposing local variations of level during subsidence or elevation of the land, the chances would have been as much in favour of a greater as of a lesser depth than that just stated.

a hollow noise as it beats against the projections, and sweeps round the recesses of the great rocky ramparts of Snowdon, suggesting the time when they were assailed by sea-waves in a similar manner, but with immeasurably greater force.

General Character of Snowdonia.—The whole range of Snowdonia has been hollowed out into cwms like cells in a honey comb—these cwms generally separated by narrow edges, ridges, or strips of table-land. The summits of the highest mountains are merely the highest parts of these partitions. These summits usually occur where three or more partitions diverge from a central point; in other words, the mountain-summits appear to be supported by buttresses. The cwms have obviously been undermined backwards, or towards each other. The undermining agency has, in a few places, left a considerable breadth of table-land, or of gradually-swelling mountain. In most places the remaining strip is narrow; in many places the merest edge separates the cwms. Here and there the undermining agency has over-done its work, for the mountain has been cut into far beyond its axial ridge (as in the case of Snowdon), or even divided so as to leave only a col or pass. By the back-to-back or back-to-side excavation of cwms, it is probable that many deep passes may have been formed. It is worthy of remark that the valleys of the more elevated part of Snowdonia are either cwms, or amphitheatrical-shaped, at their inner terminations. There are few instances of large valleys narrowing off and thinning out upwards, though at a lower level on the slopes of the mountains, valleys of this shape have been excavated by rivers. The above remarks are quite as applicable to certain parts of the Lake District as to Snowdonia.*

* For remarks on the points of the compass faced by cwms, see *Origin of Cwms*.

Principal Cliffs of Snowdonia.—Among the steepest, highest, and most continuous cliffs of the Snowdonian range of mountains are the following: those on the N. and NE. of the peak of Snowdon, and on the S. of Llyn Llydaw; Clogwyn du'r Arddu; the great cliff at the head of Cwm Llafar; the E. and W. sides of Tryfan; cliffs above Cwm Bochlwyd, Cwm Idwal, and some of the cwms on the W. side of Nant Francon, &c. For descriptions of them, see *Excursions*.

CHAPTER VII.

INLAND ESCARPMENTS, ETC. *continued*—ESCARPMENTS, CWMS, AND CLIFFS OF THE LAKE DISTRICT.

In the lake district nearly all the escarpments and more abrupt features occur to the NW. of the band of Coniston (Bala) limestone which runs across the country. They have been formed in Lower Silurian rocks. From a SW. and NE. line passing through the northern part of Windermere Lake to a parallel line cutting Keswick Lake or Derwent Water, the rocks consist principally of submarine lava, ashes, slates, grits, etc. of Llandeilo age.* To the NW. of this line are the Skiddaw Slates. (Lower Llandeilo and Upper Primordial?) To the SE. of the great Skiddaw Slate anticlinal axis, the strata preserve a general dip to the SSE., with numerous local anticlinals and variations. The long escarpments do not generally run along the strike of the beds, nor always along the strike of the cleavage. In a great measure, irrespectively of strike or dip, they present a remarkable tendency to face the E., excepting in the

* Their exact place in the Llandeilo series has not yet been fixed.

western part of the Lake District. This characteristic of the escarpments I first noticed while examining Howe's model of the Lake District at Bowness.*

Escarpments facing the East.—Among the localities in which the escarpments approximately face the east may be mentioned the following: the western side of Kentmere (which embraces one of the highest and steepest cliffs of the Lake District); the western side of Windermere; the western side of Kirkstone Pass, Scandale and Rydal valleys; the Dow Cliffs, above Goat's Water; the eastern side of the Old Man and Wetherlam ridges, and the western side of Greenburn Valley; the eastern and south-eastern sides of Black Combe; the cliffs of Pavey Ark; the eastern side of Scawfell, and the Crinkle Crags; the western sides of the valley containing Thirlmere; the eastern side of Helvellyn; the eastern and south-eastern sides of Saddleback, &c. On the borders of the Lake District, to the NE. of Kirkby Lonsdale and NE. of Sedbergh, there are some fine escarpments which mainly face the east.

Escarpments facing various Directions.—In the western part of the Lake District, and occasionally elsewhere, the faces of the escarpments are variously directed. Among these may be mentioned, Wastdale Screes; the escarpments on the south side of Ennerdale, and the south-west side of Buttermere and Crummock valley; Honister Crag and the escarpments opposite (see *Passes*); the escarpments of Hindscarth, Whiteside, Grisedale, and Skiddaw; the escarpment under the Langdale Pikes; the escarpment and cliffs on the eastern side of Derwent Water, &c.

The escarpments of the Lake District are often the steepest side of a valley, the other being a gentle slope,

* I forget whether Mr. Howe did not first point it out to me.

but they are as frequently the rocky crest of a slope which is strewn with screes and débris. Some of them are very straight and continuous. Others consist of a succession of cwms. As in Wales, there are numerous narrow ridges or strips of table-land escarpmented or hollowed out on both sides, but generally much more on one side than on the other. How far the escarpments of the Lake District follow fractures or faults, as many of the passes and valleys undoubtedly do, would require a very particular survey to ascertain. Those faults which have brought soft and hard beds into proximity have in all countries largely determined the direction of the denudation. In other respects denudation, so far as regards escarpments, would appear to have ignored faults to a striking extent, though fractures, without much vertical displacement or lateral disturbance, may have influenced the direction of escarpments to a considerable degree, without any traces of the fractures being now discoverable.

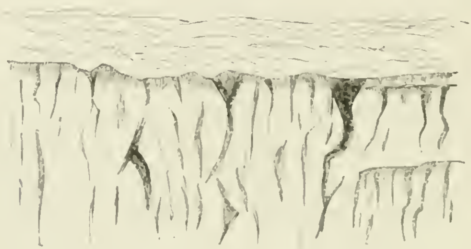
Helvellyn.—The eastern side of this well-known and frequently-ascended mountain exhibits a winding north and south escarpment distantly resembling that of Snowdon. The mountain to the west slopes for some distance very gradually. The highest point, according to the Ordnance Map, is 3,118 feet above the sea. Immediately under it, at a depth of 762 feet, and 2,356 feet above the sea, is Red Tarn. The cwm in which this tarn is situated has the buttress called Swirrel Edge on the north, and Striding Edge on the south.* The latter is separated from the part of the escarpment called Lad Crag by a chasm. To the north of Swirrel Edge is Keppel Cove Tarn, 1,825 feet above the sea, and 1,000 feet below the adjacent part of the escarpment of

* The danger of walking along Striding Edge has been exaggerated.

Helvellyn. The cliffs above Red Tarn, and in other places along the east side of Helvellyn, are neither so high or so steep as in many parts of the Lake District.

Wanthwaite Escarpment.—On the southern side of Threlkeld Vale, and eastern side of the tributary valley called St. John's, is Wanthwaite Crag, a small part

Fig. 36.



Rain-ruts, or Rakes, on Wanthwaite Crag.

of which, with rain-ruts or rakes, is represented in Fig. 36. It bounds an approximately level table-land, the highest point of which, White Pike, is 2,380 feet above the sea.

Saddleback.—The gently-rising table-land of Saddleback is abruptly bounded towards the SE. and E. by a very fine continuous escarpment, the highest point of which is Linthwaite Pike, 2,847 feet above the sea. This point is a projecting headland with precipices on three sides, somewhat resembling, but not nearly so grand as Snowdon. Its height above the wide vale below (now traversed by the railway from Penrith to Keswick) is not less than 2,400 feet. Beneath the upper or more continuous part of the escarpment, the slope is deeply rutted by rain-streamlets, and in one place, at least, by a temporary torrent during 'the bursting of a thunder-cloud,' or waterspout (date unknown), instances of which have from time to time occurred in the Lake District. The crest of the escarpment, though winding, is not much indented by regular cwms, though at a lower level several deep hollows are bounded by edges. Among the latter, Razor Edge is somewhat celebrated. In Green's 'Guide to the Lakes' it is asserted to be so narrow as to necessitate progression by bestriding it, or creeping along on one side, with hands over the top. Scales Tarn is on the south side of this edge, with a precipice of Skiddaw Slate, called Tarn Crag, behind. Whether stars during daylight can sometimes be seen reflected from this tarn, is not a question which comes within the scope of this work. Bowscale Tarn, farther north, is still more sheltered from the sun's rays by cliffs.* In Saddleback the Skiddaw Slate beds dip to the SSE., at a high angle. This dip is continued across the Vale of Threlkeld as far as the greenish-grey rock district, with local reversions. The escarpment of Saddleback probably follows, at least in some places, the strike of the cleavage, but it has not yet been sufficiently examined to justify our speaking with confidence on this point.

Other Escarpments and Cliffs of the Lake District.†—The narrow ridges of Skiddaw may be regarded more as scree-strewn slopes than escarpments. These ridges may be likened to a series of ramifying roofs of houses, the gables of which appear peaked. On walking along Whinlatter Pass, several steep escarpments, bounding cwms, may be seen on the south side, especially under the ridges forming a continuation of Grisedale Pike (2,513 feet above the sea). Between Whinlatter Pass and the Vale of Newlands, there is a wonderful series of

* Still farther north, in the granitic and felspathic trap districts of Carrockfell and Caldbeck fells, there are some striking escarpments and cliffs.

† Wallow Crag will be described in *Excursions*.

narrow ridges, table-lands, escarpments, and cwms (beautifully represented on the Ordnance Map, now in course of being shaded, Feb. 1868), carved out of the Skiddaw Slate formation. On the SW. side of Buttermere Vale there is an escarpment of greenish-grey rocks, porphyry, and syenite, consisting of three cwms, with three headlands, culminating in the peaks called Red Pike, High Styie, and High Crag. Bleaberry Tarn is situated in the middle cwm, which very much resembles a sea-coast cove.* On the north or Ennerdale side of the Pillar Mountain there are several fine crags. Fig. 37 represents one of them, called the Pillar Rock. It has been copied from a sketch by Mr. Whitehead, of the Whitehaven Infirmary.† The rock is a mass of fine porphyry.

The dale partly occupied by Wastwater is a long narrow tract, ranging from about 200 to 300 feet above the sea-level. Professor Phillips, at the Birmingham meeting of the British Association (1865), mentioned that after surveying this dale, he had come to the con-

* The streams from Bleaberry Tarn and Lingcomb (under Red Pike) have done so little in the way of denudation, that their channels do not disturb the straightness of the contour lines of the vale of Buttermere as represented on an inch to the mile map. Why, then, credit them with having excavated the cwms?

† On September 24, 1850, Mr. Whitehead ascended this rock, and found two slips of paper in a ginger-beer bottle, with the following inscriptions:—'Lieut. Wilson, R.N., Troutbeck, ascended the Pillar, May 6, 1848, and left this bottle as a memento of the same.'—'Charles A. C. Baumgartner, August 24, 1850. Cambridge.'

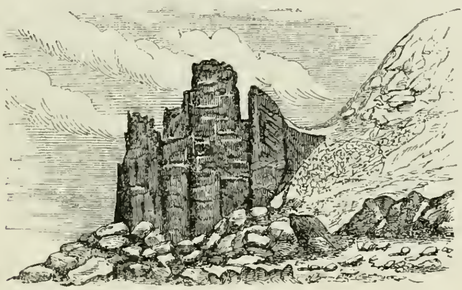
Mr. Whitehead again ascended on May 24, 1853. The ginger-beer bottle left by Lieut. Wilson was still there, but the papers were gone, and in their place a nest of black beetles! The beetles were dislodged, and a slip of paper with 'God save the Queen' written on it was left in the bottle.

Charles William Hartley, a young man from Bradford, Yorkshire, ascended Friday, May 24, and Monday, May 27, 1861.

Mr. Whitehead a third time ascended, August 27, 1861, and found the paper left by Mr. Hartley.—*From an article by the Author in Geol. Mag.* vol. ii. p. 306.

clusion that the basin of Wastwater could not have been scooped out by a glacier. On its south-eastern side is the magnificent escarpment (already noticed), called the Screes. It extends in an unbroken line for three miles. From the summit, to perhaps a third of the way down, it consists of a range of crags. Beneath, the rocks *in situ* are concealed under a vast accumulation of loose and coloured débris, which slopes into the lake. We cannot say how much steeper the whole of the escarpment may once have been. One thing is certain—that the vale and lake-basin beneath could not

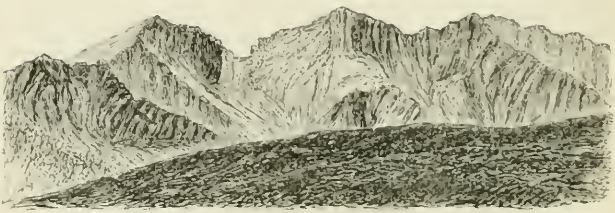
Fig. 37.



The Pillar Rock, Ennerdale.

have been scooped out by a stream, as a stream could not have flowed up hill. It seems equally obvious that the escarpment could not have been *formed* by rain and frost, as these agents are now doing all they can to destroy it. It is true that they may for a time preserve an upper line of crags, by wearing them back; but it requires but little knowledge of dynamics to perceive that a continuance of the process must obliterate the escarpment, unless the ocean again should come up Wastwater Dale, and carry away the surplus screes. The level of Wastwater is 204 feet above the sea, and that of the highest part of the Screes escarpment 1,983 feet. The height of this escarpment above the lake varies from 1,500 to nearly 1,800 feet. The rocky escarpments on the eastern sides of Scawfell and Scawfell Pikes, are perhaps more calculated than any other part of South Britain to suggest ideas of rugged desolation, tumultuous disorder, and chaotic sublimity. They present the appearance of the interior of the earth having been ruthlessly exposed to the light of day (see Fig. 38).

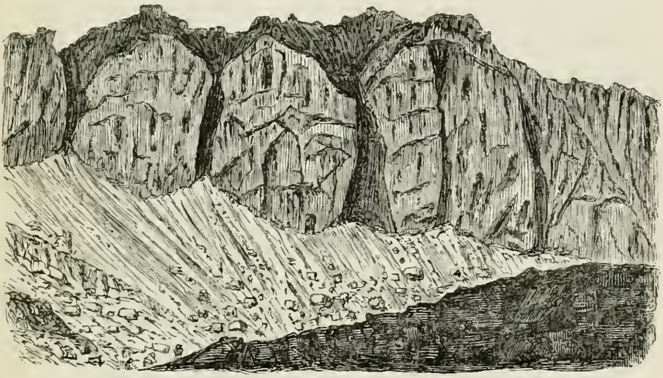
Fig. 38.



Scawfell, as seen from Coniston Old Man.

One of the steepest (at least 60°) escarpments in the Lake District slopes down from the Langdale Pikes on the south side. Its height varies from 1,800 to about 2,000 feet. The cliffs of Pavey Ark, which slope down into the basin of Stickle Tarn, at about 50°, are very imposing. The northern rocky slope of the great Langdale valley between Millbeck and Langdale village, is very deeply rutted by transverse streams, the steep-sided channels of which show the very distinctive form produced by fresh-water denudation. Among the finest faces of bare rock in the Lake District, are Eagle Crag, in Stonethwaite, Borrowdale; St. Sunday's Crag, Grisedale; Raven Crag, near Thirlmere; and Dow Crag, which overhangs Goat's Water near Coniston, the height of which, including screes, is 900 feet (see Fig. 39).* Among the most singularly-shaped crags is the well-known Castle Rock, St. John's Vale. In the eastern part of the Lake District, there are several deep cwms with tarns, and surrounding steep cliffs. Among them may be mentioned the basin of Blea Water, at the head of

Fig. 39.



Dow Crag, from the Southern Slope of the Old Man. (Goat's Water concealed by the foreground.)

Mardale. The tarn is 1,584 feet above the sea. The narrow edge bounding it on the north is nearly 500 feet higher than the tarn. High Street, on the west, is 1,079 feet higher.†

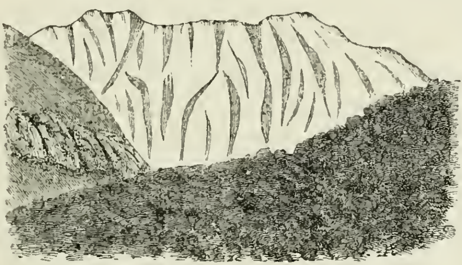
* For a description of this precipice see *Excursions from Coniston*. For references to other precipices in the Lake District, see *Passes*, chap. xiv.

† Many years ago, the periodical gathering for fox-hunting, wrestling, &c., was held in Martindale. A man named Dixon fell over Blea Water Crag (which must be at least 900 feet in height, including screes). None of his bones were broken, but he was severely bruised, and nearly scalped. In his descent, he struck against projecting rocks, afterwards called 'Dixon's Three Jumps.' As soon as he got to the bottom, he raised himself on his knees and said, 'Lads, te fox is gane out at hee end, leg [lay] te dogs on, and I'll come syun,' and then fell down insensible, but lived for some time after in Kentmere!—*From an Old Guide Book.*

Origin of Screes.—The existence of screes, or a talus of débris partially concealing a cliff, is a clear proof that the cliff was at one time more precipitous than at present, and that the cause which formed the cliff was at once capable of undermining and removing the fallen débris. In the Lake District, screes in many places bury the bases of cliffs ; in others, they strew the ground which slopes away from under the cliffs. In either case they tend to reduce the steepness of slopes. Where the slope beneath is sufficiently steep and immediately subjacent, frost, by chipping off its face, may keep up the steepness of a cliff for a shorter or longer period ; but as the cliff is worn back, the vertical extent of it which is shored up and protected by screes must increase, and the part undergoing dilapidation must decrease, so that in time the cliff must disappear. In many parts of the Lake District, the screes under cliffs are very superficial, showing that little decay of the cliffs has occurred. In other places, the cliffs continue to preserve their originally cleanly-swept bases. There are parts of the Lake District where the screes could not have fallen down from above, and where they must have been accumulated (sometimes apparently thrown up) by the action of a body of water. There are other places where fallen débris would seem to have been arranged under water. (See *Angular Drift—Denudation during the Great Glacial Submergence.*) Screes often strew slopes and hill-sides where regular cliffs are absent. Though everywhere it is easy to form an exaggerated idea of their thickness, there can be little doubt that in some places they have greatly modified the outline of the ground. In many valleys it is often difficult to distinguish screes from glacial moraines. The Lake District is more remarkable for screes than Wales, and for the same reason its escarpments and cliffs are generally less steep than in the principality.

Origin of Rakes.—The deep vertical indentations in the faces of cliffs (called 'rakes' in the Lake District) which, as Wordsworth long ago observed, often ramify like the shape of the letters V, W, Y, are probably in many places the undilapidated inlets left by the sea as it undermined and removed the blocks of rock by the abstraction of which the inlets were formed. But many rakes, especially in the Lake District, have apparently

Fig. 40.



Rakes on Great End, as seen from Borrowdale.

resulted from the long-continued action of rain, assisted by frost and gravitation. Rain-water acts most effectively where it becomes collected in previously-formed crevices, which, by the loosening of blocks, and the carrying down of fragments and splinters, it gradually enlarges into rakes. Screes are often found under rakes in ridge-shaped deltas. This is perhaps nowhere exemplified more strikingly than on the northern side of Cader Idris, under the headland called the Saddle. Rakes, however, are in general more gaping in the Lake District than in Wales, and among the principal may be mentioned Lady's Rake, in Wallow Crag, near Keswick, and Lord's Rake, on the south side of Mickledoor Pass, Scawfell. But I know of no finer exhibition of ramifying rakes than on the face of the magnificent rocky slope of Great End. (Fig. 40.)

Origin of Scarped Peaks.—In the Lake District and Wales, it would appear that the original* undulating table-land or gradually-swelling hills, must in many places have received the form of circumdenudated cones, peaks, or short ridges. The subsequent denudation or denudations which assailed the land at lower levels, and wore back escarpments and cwms, must either have completely carried away these projections, scarped their sides, or left them entirely unscathed. The majority, probably were left with scarped sides. There are many instances of scarped cones and peaks in the Lake District and Wales. The following come more or less under this denomination :—Old Man, Coniston ; the highest peak of Saddleback ; two eminences between the summit of Skiddaw and Bassenthwaite Water ; White Pike, near Wanthwaite, and several eminences to the SE. ; Grisedale Pike ; the highest part of Whiteside, and some eminences in the neighbourhood ; Red Pike, to the south of Crummock Water, and a number of eminences crowning the ridge to the south of Ennerdale Valley ; Kirkfell, &c. In Wales the peak of Cader Idris furnishes the best example. About a third of its circular contour has been carried away by denudation. It is difficult to say whether the original culminating point of the gradually-swelling dome of Snowdon has vanished, or whether it has been preserved in Y Wydffa. One thing is certain, that Y Wydffa has been relentlessly scarped, especially on the north-eastern side. Among

* The term is here and elsewhere in this work applied to the form of the ground before the last great denudation or denudations by which the present shape of the surface was produced.

other scarped peaks, cones, or eminences in Wales, may be mentioned Carnedd Dafydd, Carnedd Llewelyn, several eminences on the west side of Nant Francon, Moel Siabod, Moel Wyn, &c. But scarped mountain-summits are not confined to the more elevated hilly regions of South Britain. The Sugar Loaf, near Abergavenny, furnishes a fine example, and others at inferior levels might be mentioned. The cause of the scarping of peaks must have been one independent of the drainage of the land, for no subaërial action could have accumulated to an extent capable of scarping within a few yards of the highest points of the surface—that is, so far as acting from above is concerned. With regard to the alleged undermining power of rain, it may be remarked that scarped peaks often occur where no softer under stratum could have facilitated retrogressive denudation. The scarping in many instances must have been an unconditional process, the operation of a power assailing the hills from without, and capable of carrying away not merely fragments but loads of débris, as the receding cliffs fell down in masses, so as to keep the highway of denudation clear and unencumbered. This may be inferred from an inspection of the cliffs and cwms under many of the scarped peaks of England and Wales, as illustrated in other parts of this work. (See *Origin of Cwms, Escarpments of Snowdon, &c. &c.*)

CHAPTER VIII.

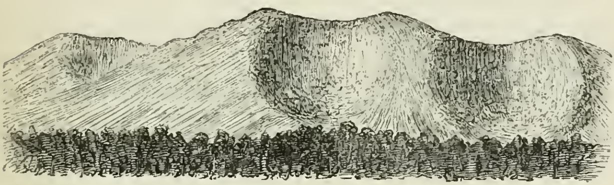
INLAND ESCARPMENTS, ETC. *continued* — CAMBRIAN * ESCARPMENTS AND CWMS — THE MALVERN HILLS.

The Malvern Hills are mainly composed of an irregular kind of gneiss (see *Excursions*). On the western side the slope graduates downwards into very uneven ground, The eastern side is much steeper, and rises from a plain. Along its base there are accumulations of angular fragments of hard rock derived from the hills, imbedded in earth and clay. The fragments become smaller in the direction of the Severn, as may be seen at Hanley Green; and in various places (the lower part of Mill lane, for example) they are interstratified with denuded and redeposited Keuper marl. In many places, near to the hills, the angular drift has been spread out into beach-like expanses, longitudinally level, but sloping away from the hills. Its surface is often as smooth and uniform as that of any sea-beach. The included fragments have evidently been transported by waves or currents, ordinary or paroxysmal, as in most places they occupy positions where they could not have fallen, and where rain could not have carried them. The sea, as already shown, must have washed the base and extended up the face of the Malvern Hills at the time when the plain between them and the Cotswold escarpment was the bed of the 'Malvern Straits.' The eastern

* Sir Roderick I. Murchison (see *Siluria*, 4th ed.) advances good reasons for regarding the metamorphosed rocks of the Malvern Hills, so very ably described by Dr. Holl, as not necessarily of greater antiquity than the Cambrian strata of Anglesea. I have not therefore used the term Laurentian proposed by Dr. Holl, though I wish to leave the question open.

side of the Malverns is deeply indented by gulleys, and hollowed out into cwms. Among the latter, the three in the neighbourhood of Malvern Wells (represented in Fig 41), are perhaps the most worthy of consideration. They have been scooped out of hard hornblendic and micaceous gneiss, with quartzo-felspathic and granitic veins, and do not appear to be explicable by assuming the waste of soft rocks, for here the trappean protrusions which in the gulleys farther north have guided the denudation, are comparatively absent.* Of these three cwms, one may be called dry; all the water coming

Fig. 41.



Cwms near Malvern Wells, as seen from a distance of about two miles.

from another, generally finds its way through a small pipe, from which it spouts on the road-side; and though the runlet from the third may not make so great a display of its denuding power in the shape of an artificial cascade, it may in the eyes of subaërialists be equally capable of scooping out a cwm. The springs (one of them called Holy Well) from which the two streamlets flow are situated at the bottom of the cwms, and it scarcely seems necessary to enter into a refutation of the

* It is true that there are small trappean intrusions and protrusions, faults, fractures, and perhaps other irregularities of structure, in the areas occupied by these cwms; but though these may have been sufficient to facilitate the commencement of the excavating process, this process must have been sufficiently powerful to make progress in a great measure irrespectively of internal structure.

doctrine that these springs have excavated the cwms—more especially as there is not the slightest indication of their now carrying on the process of undermining backwards. The cwms have been cut back beyond the axial ridge of the Malverns. Their surfaces are covered with soil, grass, and shrubs. The few screes which appear above the grass must have been left by an agency which has now ceased to act, as they occur in situations above which there are no projecting rocks from which they could have fallen. The form of the cwms is very curvilinear, with few or no rain-ruts, and one of them (Holy Well) embraces nearly three-fourths of a circle. Their floors slope towards their outlets.

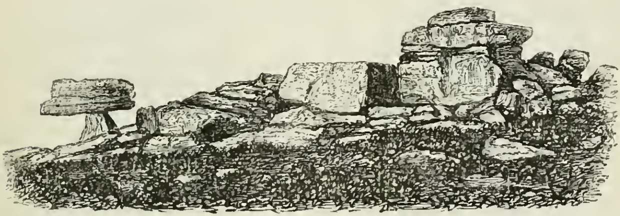
Farther south there are many cwms and valleys I have not visited. On the north-west side of the North Hill there is one of the most perfect specimens of a shallow cauldron, or smoothly-rounded cwm, I have yet seen. At first sight it is difficult to resist the idea that it was whirled out in the eddy of a current or 'wave of translation.'

CHAPTER IX.

ORIGIN OF THE GRANITIC TORS, ROCK-BASINS, ETC., OF DARTMOOR AND CORNWALL.

On any intelligible theory of the upheaval of the so-called igneous rocks of Dartmoor, the present cannot be the original outline their surface presented. The hills and ridges are partly if not wholly the effect of the denudation of the intervening depressions, and the tors are evidently the remnants of a former lateral extension of the jointed masses of which they are composed. Some of the tors exhibit clear indications of their having been once connected with other tors, and all of them may be regarded as the unscathed monuments of a stupendous denudation by which the adjacent parts were removed. The rounded forms of many of the hills and rocks may have been enhanced if not caused by icebergs (see *Boss and Tail*). But the present shape of most of the tors or rocky piles of Dartmoor can be best explained by the action of sea-waves

Fig. 42.



Part of the Rippon Tors, Dartmoor, showing indications of blocks having been bodily removed.

and currents. The ground on which the tors stand is sometimes perfectly flat, and the slopes stretching away from the bases of other tors very often present absolutely straight lines (when viewed in profile) for great distances. Such tors may be regarded as situated on, or forming the upper terminations of, 'plains of marine denudation.' It may likewise be observed that tors generally occupy the summits of eminences where the sea may not only have surrounded them, but washed over them and through them, and where it may be said to have had them at its mercy. The existence of tors as the crests of hills may be accounted for on the supposition of the sea having been able to circumdenudate them. But as regards atmospheric agency, it should be remembered that they occupy what may almost be called the waterless centres of watersheds. Rain has not space to acquire force or collect loose matter so as to enable it to exert much abrading power within their circumference; and as its chemical action is almost entirely limited to where it is retained in rain-pools, it may be said that what falls, generally speaking, innocuously runs off. The grass or heath comes right up to the base of many tors, par-

Fig. 43.

Bowerman's Nose.

Fig. 44.

The Cheesewring.

ticularly on one side, and as no gradual shading off into parts now undergoing granular decomposition is generally apparent, there must have been a sudden cessation of the 'sweeping denudation;' it must have finished its work within a given period; the natural edifice must have received its last touch when Dartmoor last rose above the sea; and since the final embrace of the denuding agent, the powers of the air have not had time to mar the general effect. On one side of some tors the assailed blocks must have been carried clear away in a manner that ice will not account for, and which is altogether inexplicable on the subaërial theory. In the vicinity of other tors we find heavy blocks of granite out of place and piled on blocks likewise out of place, on nearly level ground—a phenomenon to which a mere trickling, dribbling, wasting, frittering agency, such as rain, could never have given rise. Many cleanly-cut passages through the tors have evidently been left by a wholesale clearance of blocks, and where these passages are wanting, the indentations, inlets, and incipient caves point to the insinuating, disentangling, and removing agency of breakers.* The smaller crevices are not always, as has been imagined, the effect of the enlargement of joints by rain, and therefore stages in the passage-forming process, but the original joints themselves, with their rain-proof sides minutely corresponding.

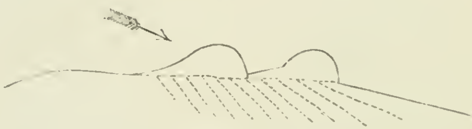
Rock-pillars.—Among the tors of Dartmoor, and in the granitic districts of Cornwall, there are many rocky projections more or less regular, to which this term may be applied. Bowerman's Nose, near Manaton, and the Cheesewring, near Redruth, are perhaps the most striking. The impression these and other pillars must leave on an unbiassed mind is, that a powerful cause must have carried away the blocks by which they were once surrounded (see *Brimham Rocks*). A little inspection will be sufficient to show that the circumdenudation has been equal to the removal of whole blocks, and not merely to chips or grains. In the case of these and many other rock-pillars, there are no indications of the parts removed having been softer than the parts left

* In many places blocks, large and small, may be seen lying at a short distance from a vacancy in a neighbouring cliff from which they have clearly been abstracted and carried along on nearly level ground. I saw a remarkable instance of this on one side of the rocky hill above Bowerman's Nose, near Manaton. In the neighbourhood, a large flat stone showed indications of its having been split, and the two halves separated at one end like the letter V.

unscathed.* Indeed, the path of denudation appears sometimes strewn with the very blocks which once built up the massive structure of which the pillar is the only part now remaining *in situ;* and these blocks are often in positions where they could not have fallen, and where, therefore, they must have been carried.

In illustration of the above remarks on the origin of tors and rock-pillars, it may be stated that the Hountor Rocks present a series of cliffs formed by the removal of whole blocks, and of roofless caves, equal to the width of from one to three blocks, from which whole blocks must have been abstracted. The two Hey Tors (which may

Fig. 45.



Outline of the Hey Tors, as seen from Ingsdon Hill. The dots show the position of the scattered blocks.

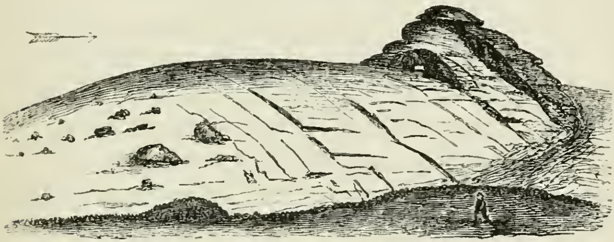
be seen at a distance of ten miles from the railway at Newton-Bushel), exhibit somewhat similar phenomena, though they are principally remarkable for the apparent indications they present of the denuding agent having come from the SSE.—smoothing the projecting rocks up an inclined plane, stripping bare the sides of the tors, and scattering myriads of blocks and fragments towards the NNW., along a slightly-inclined surface, the profile of which, from a distance, presents a per-

* The tors and rock-pillars are generally found in the zones or areas of hard granite which occur in approximately-cubical blocks, and not in those districts where spheroidal hard masses of granite are imbedded in a soft matrix. But even in the latter districts the removal of the soft granite by rain must in many cases have been impossible, owing to the absence of sloping ground.

fectly straight line.* How far floating ice, or icebergs, may have assisted the sea in accomplishing so great a result, it would be difficult to determine. The scattered blocks might be regarded as the underminings of the NNW., or precipitous sides of the Hey Tors, scattered by revulsive wave-action, were it not for the fact that the opposite sides of the tors have been much smoothed and rounded, and that quite irrespectively of the structure of the rocks.

'*Boss and Tail,*' *near Moreton-Hampstead.*—The Blackenstone Rock, about two and a half miles to the east of Moreton-Hampstead, is one of the most striking

Fig. 46.



Blackenstone Rock.

granitic bosses in Europe.† On account of its elevated position it can be seen from a distance of many miles. The north-west side must be nearly 200 feet high. The most projecting part of this boss consists of cross-jointed

* These blocks and fragments consist of at least two kinds of granite—a reddish fine-grained variety, and the common coarse-grained variety, with large oblong crystals. The varieties may be both seen *in situ*, one above the other, on the western side of the more westerly of the two tors.

† Since first writing on Dartmoor, I have found that the very talented author of *Frost and Fire* briefly mentions the Blackenstone Rock, and regards it as having been smoothed by an iceberg from the NE. He does not, however, refer to its tail. He likewise notices the Hey Tors, without referring to the direction of their tails, and the position of the scattered wrecks.

or stratified hard granite. It has been rounded totally irrespectively of structure. A close inspection will show that rain has only roughened its surface. It has been swept clean of débris all round excepting a few stones on its north side. On the north-east side it graduates into a tail, which presents a strikingly-rounded and smoothed appearance. According to the theory of its having been denuded by a grounded iceberg from the NE., the tail would be in front, or on the 'upstream' side (see Fig. 46, in which the tail is fully represented, and the boss very much foreshortened).*

Rock-basins.—The reader would do well to visit the Druid's Altar, near the Blackenstone Rock, before it is quite quarried away—before its rock-basins are exploded by gunpowder, and its 'ribs of beef' chopped up. The latter term is applied to six or seven small ridges and furrows running down both sides of a large ridge of rock. Though rain is roughening the ridges, it is certainly not forming the furrows, which are covered with moss. On this and the neighbouring parts of the Druid's Altar, there are many rock-basins. One—rather large, very regular, and smooth-sided—is partly filled with grass-covered soil. In other places there are small, round, and deep, as well as shallow basins, like pot-shaped cavities on the sea-coast or in the channel of a river. In one of these I observed rain-water in a state of lively gyratory motion produced by wind, but a little reflection showed that the round form of the basin was the cause, and not the effect, of the whirling of the water. On Hell Tor (commonly called Heltor Rock) there is a very large basin, at least 6 feet in diameter by 3 feet

* Since seeing rounded rock-surfaces on a considerable scale in the district of the Little and Great Orme's Heads, North Wales, where the sea offers a sufficient explanation, I have not felt quite so confident relative to the tailed tors of Dartmoor having been rounded by ice.

deep, one side of which is of a perfectly semicircular form, and evidently hollowed out irrespectively of structure by a forcible agency. It is broken down on one side by a rent, so that it can hold no rain-water, and it is worthy of remark that the rent has had no influence on the curvilinear form of the basin. On the top of Ingsdon Rock, near Moreton-Hampstead, there is a basin which has been excavated right through the uppermost bed or jointed mass of granite, so that the rain-water now escapes through the crevice beneath. It occurs on the highest part of the rock, so that rain-water could not have acquired the form of a gyrating cascade. One side of it is very curvilinear, and as smooth as if worked by a chisel. Its general form is elliptical and curvilinear, with the exception that rain has evidently dilapidated it on the left-hand side. Here, as everywhere else, rain is tending to break down and not to form curvilinear rock-basins. The size of the Ingsdon basin, if I remember rightly, is about 3 feet in diameter.

Origin of Rock-basins.—Mr. Ormerod, F.G.S., of Chagford, the principal writer on rock-basins, seems to follow Dr. MacCulloch and other early geologists in attributing all natural rock-basins (away from the channels of rivers) to atmospheric action. But from a somewhat particular examination made during stormy weather, I think they ought to be divided into two kinds, pluvial and marine. The first would appear to be formed as follows:—A slight hollow on the upper surface of a rock collects a little rain-water, which, through its chemical action and agitation by wind, gradually detaches a little fine detritus. A continuance of the process deepens the hollow until it reaches the lower limit of the agitated water. The small wind-waves enlarge the cavity laterally, forming a miniature line of cliffs, which (except by mere accident) can never acquire any curvilinear regularity. The denuding process is prevented from becoming choked up by the fine detritus being blown out by the wind in dry weather. In this way shallow, approximately flat-bottomed, rough, and steep-sided rain-pools are formed,* but they are distinct (excepting where one kind of hollow has been superimposed on another) from basins with smooth, regular, and perfectly-curved sides. The latter occur chiefly, though not always, on the more or less inclined

Fig. 47.

Rain-worn Basin.

Fig. 48.

Wave-worn Basin.

surfaces or sloping sides of rocks, and are often open on one side, so that they contain little or no rain-water. They are fac-similes of hollows now ground out by waves wielding sand or stones on sea-coasts, or among the projecting rocky islets of archipelagoes. On the Dartmoor granitic area, these basins, in spite of the roughening action of rain, retain a smoothness equal to that of many stone basins chiselled out for domestic use in the neighbourhood. If the marine theory can be disproved, their artificial origin is the only explanation left, for they are generally situated on heights remote from the channels of rivers.†

* The curvilinear rock-basins are *sometimes* flat-bottomed and steep-sided, especially when the bottom is the surface of an under-stratum.

† Since the above was written, I noticed a striking illustration of the roughening influence of rain on the Great Orme's Head. The smoothly hollowed out, saucer-like depressions on the nearly horizontal faces of the limestone strata are, here and there, in course of being wrinkled by rain-

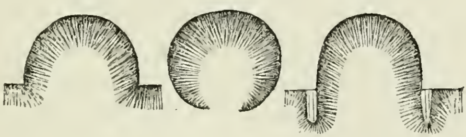
CHAPTER X.

FACTS AND CONSIDERATIONS BEARING ON THE ORIGIN OF CWMS AND SMALL LAKE-BASINS.

The Welsh word cwm is a very convenient name for a class of hollows which form the most characteristic scenery of a great part of North Wales, and which are more or less prevalent in other parts of South Britain.

Typical form of Cwms.—Cwms generally exhibit a tendency in the direction of the following forms: a circular basin with its sides gradually lowering and vanishing towards an outlet (Fig. 49), its sides abruptly

Fig. 50. Fig. 49. Fig. 51.



terminated (Fig. 50), or its sides abruptly terminated with sub-boundaries (Fig. 51). A cwm differs from a ravine, which narrows off and thins out upwards, and tends to its maximum development downwards. It is likewise distinct from a longitudinal valley with a transverse gorge or outlet, though hollows intermediate between the two may sometimes be seen on the sides of mountains or table-lands.

Transverse Sections of Cwms.—In profile, cwms present every gradation between a shallow concavity with a

pools, and the successive stages of corrosion can be distinctly traced from the uninvaded curvilinear basin (the effect of ancient wave-action) to a cavity with toothed sides and irregularly-pitted bottoms (Figs. 47 and 48).

steeply-sloping floor and a deep basin. Where cwms occur in escarpments and cliff-lines instead of gradual slopes, their bottoms present much the same transverse outline.

Boundaries or Walls of Cwms.—The declivities encircling cwms are generally steeper towards the back or towards one side than towards the outlet; in other words, the declivities are generally steepest where the encircling ground is highest. Many cwms are surmounted by mountain peaks, and under the peaks the declivities are steepest. Instances: Glas Llyn Cwm, under Snowdon, the steepest side being beneath the peak, and the most sloping parts behind (at the place where the Capel Curig and Llanberis routes join), where the ground declines, and in front close to Glas Llyn; Cwm Llafar, under Carnedd Dafydd; Cwm-y-Gader, under the peak of Cader Idris, &c. &c. This would seem to point to an undermining agency; the effect of the undermining having been greatest where the weight of the superincumbent mass caused the greatest downfall. It would likewise seem to point to an agency capable of carrying away the fallen débris, and thereby preserving the steepness of the cliff.

Lateral Boundaries of Cwms.—Generally speaking, the lateral boundaries of cwms situated on gentle slopes gradually vanish. But in many instances the lateral boundaries terminate abruptly, either in rocky cliffs or steep scarps, as in the following instances:—The triple-headed cwm in which Llyn Dwythwch is situated, a few miles SW. of Dolbadarn, and on the right hand of the Llanberis route to Snowdon; Cwm Glas, on the north side of Snowdon; Glas Llyn Cwm, under the peak of Snowdon; the cwm on the eastern side of Moel Siabod; Cwm Llugy, south of Carnedd Llewelyn; Cwm Dulyn, NE. of Carnedd Llewelyn (see *Excursions*). Many cwms have their lateral boundaries on *one* side abruptly terminated, as in the following instances :—Cwm Llafar, Cwms Idwall, Bochlwyd, and Tryfan (at the head of Nant Francon), Cwm du, on the north side of Mynydd Mawr, &c. Cwms in regular escarpments have their lateral boundaries terminated by one or two headlands, as in the case of Cwm-y-Gader, Cwm Aran, and Cwm Llyn (Cader Idris), several cwms in the Lake District, and a number of cwms in the oolitic escarpments of England; or their lateral boundaries, partly terminating in headlands, are resumed at a lower level, and vanish gradually or suddenly.*

Irregularly-shaped Cwms.—Some of the cwms of Wales are very irregular in detail, owing to the varying hardness and softness of the rocks, &c., but their general contour is still curvilinear. Instances :—Cwms Llyffaint and Upper Cwm Caseg, on the E. and NW. of Carnedd Llewelyn, &c. Some cwms are more or less angular in shape, such as Cwm Idwal, Cwm-y-Llan, Cwm-y-foel (Moel Siabod), Cwm-y-trwstyllon (Moel Wyn), &c., but these may be regarded as exceptional.

Form of the Ground under Cwms.—The general slope of the hill-side is often resumed under the outlets of cwms; sometimes there is an escarpment in front, which is merely a downward continuation of the escarpment in the upper part of which the cwm has been excavated; in other instances the floor of a cwm terminates on the top of an escarpment distinct from any slope or escarpment at a higher level. The existence of falling ground in front of cwms cannot be regarded as throwing much light on their origin, as cwms of the same form frequently present floors which are a backward continuation

* The three fine cwms overlooking the wide vale of Buttermere, and yawning under High Crag, High Style, and Red Pike, furnish good examples of this configuration.

of broad expanses of nearly level ground (see page 159). It may, however, be remarked that pre-existing frontal declivities may have facilitated the removal of the out-scoopings of cwms by sea-coast action. Instances of cwms with suddenly falling ground in front:—Cwm-y-Gader, Cader Idris; Cwm Glas, Snowdon; Cwm Bochlwyd, Nant Francon; Upper Cwm Caseg, Carnedd Llewelyn; Low Water Cwm, Old Man, Coniston; Stickle Tarn Cwm, Great Langdale; the three cwms under Red Pike, High Style, and High Crag, Buttermere, &c.

Positions generally occupied by Cwms.—As a general rule cwms show a preference for elevated districts. This is not only the case in Wales and England, but, as the Rev. M. H. Close informs me, the fact may be seen exemplified in Ireland. At high altitudes cwms generally occur (as already hinted) under the highest ridges, strips of table-land, and peaks, while, at lower levels, the brinks of cwms are generally table-lands or ridges which form the highest ground of the district. In other words, cwms generally show a tendency to approach as near as possible to the lines which separate watersheds,* and to occupy the zones where the action of subaërial running water is at its *minimum*, and where the chemical and mechanical action of aërial water, or of rain-drops, is no greater—perhaps less—than at lower levels. These facts would seem to negative the idea of the pluvial or fluvial origin of cwms.

Points of the Compass faced by Cwms.—The non-pluvial origin of cwms is likewise indicated by their tendency to open towards the NE., E., or N. Some years ago I noticed that many of the escarpments of the

* They often cut through these lines, or recede beyond the axes of the ridges, as in the case of the Malvern Cwms, Glas Llyn Cwm, Snowdon, Cwm Llafar, &c.

Lake District looked in these directions; but it was not until after the Rev. M. H. Close acquainted me with the northerly aspect of cwms in Ireland, that I was led to discover, in Wales and England, a prevalence of cwms facing the above-mentioned points of the compass too great to be accidental. Where the outlets of the cwms are not on their NE., E., or N. sides, their steepest or highest cliffs or declivities almost invariably face these points. Now we ought not to overlook the fact that the weather-beaten side of the hills of Wales and the Lake District is the SW. side, or the opposite of that on which the cwms generally occur; while we have reason to believe that district glacial action would be greatest on the N. and NE. side.

Instances of Cwms, the outlets or highest cliffs of which face the NE., E., or N.—The instances, as regards well-formed cwms, are so numerous, that there is a difficulty in finding exceptions. Amongst others the following may be noticed :—Cwm Llyn-au-afon, Cwm Dulyn, and Cwm Melyn (near Y Foel Frâs); Cwm Caseg, Cwm Llafar, Cwm Llyffaint (near Carnedd Llewelyn); Cwm Tryfan, Cwm Bochlwyd, Cwm Idwal, and the cwms on the western side of Nant Francon: Cwm Marchlyn-mawr (south of the Penrhyn slate quarries); the cwms under Moel Elio, and between it and Moel Goch (near Llanberis): Cwm du'r Arddu, Cwm Glas-bach, Cwm Glas, Glas Llyn Cwm, Cwm Llydaw, Cwm-y-Llan, and Cwm-y-Clogwyn (Snowdon); Cwm du (Mynydd Mawr), and cwms in its southern neighbourhood; the cwms on the eastern side of Moel Siabod, Moel Wyn, and intermediate mountains ; Cwm Gallt-y-Llyn, Cwm-y-Gader, Cwm Aran, Cwm Rhwyddfar, and Cwm Cae (Cader Idris); the cwms on the eastern side of the Aran and Berwyn ridges; the cwms on the northern side of the Brecon Beacons and Black Mountains ; the cwms on the eastern side of the Malvern Hills, and north-western side of the Cotswolds, near Gloucester; the cwms on the eastern side of the Old Man and adjacent ridges, near Coniston (Lake District); Blea Water Cwm, and several neighbouring cwms, east of Patterdale; the cwms on the south side of Ennerdale, under the Haycocks and Cawfell; the cwms on the south-west side of Buttermere Valley, under Red Pike, High Style, and High Crag; the cwms N. and W. of Grisedale Pike, on the south side of Whinlatter Pass; Scales, Bowscale, and other cwms on the eastern side, and north of Saddleback; the cwms on the eastern side of Helvellyn, called Red Tarn and Keppel Cove; &c., &c.

Relation between Cwms and Small Lake-basins.—It is often difficult to say whether the rock-basins containing lakes at the bottoms of cwms were formed along with the cwms, or were afterwards superimposed. Behind Glas Llyn (Snowdon), there is a scarp or cliff much steeper than the general transverse outline of the bottom of the cwm (see map of Snowdon, p. 153), which would seem to point to a superinduced deepening agency. But in most instances the lake-basins, so far as they are the effect of denudation, would seem to have been hollowed out as a part of the cwm, either by the original excavating agent, or by the subsequently modifying cause, to which both cwms and lake-basins owe their present cauldron-configuration. The section of Cader Idris (Fig. 30), will give a good idea of a cwm including a lake-basin. The lake is probably dammed up by a considerable thickness of rock under the loose stones. It is certain that a part of the frontal barrier on each side of the outlet consists of rock. This, and other cwms containing deep lakes, may be regarded as rock-basins—the frontal rocky barriers being only heightened by the stony débris; or if the stony débris forms the whole *vertical* extent of the barrier, its breadth (so far as it acts as a barrier) is limited. In the case of Glas Llyn basin, the non-rocky part of the barrier is very narrow, and apparently of limited depth. It consists of a kind of drift covered with grass, and a little moraine matter. The drift *seems* to run under the lake, so as to form a lining to the rock-basin. The lake, according to the statements of the copper miners, is very deep—at least 200 feet. (?) The under-water declivity at the back is very steep. The drift is apparently more than a lacustrine deposit. On the shores of Llyn Llydaw, lower down, the more or less rounded drift looks still more like a lining of the lake-basin rising up from under the water, instead of a mere beach formed by lacustrine waves.* But in these impressions I may have been deceived. I feel more confident with regard to rough stony débris running under the waters of some lake-basins. Llyn y Gader (Cader Idris) appears to be, in a great measure, paved with stones not *in situ*, which in some places have become closely wedged and compacted, as if they had been pressed down by a roller.

Origin of the Detrital Accumulations in front of Lakes.—I think a comprehensive survey, combined with reflection, would be sufficient to show that, in the case of some lakes, such as Llyn-y-Gader, Llyn Bochlwyd, and Llyn Dulyn, the whole of the frontal mass of débris is not moraine matter. Such a quantity of blocks and fragments could not have fallen on the surface of a glacier without rendering the cliffs rising above it much more sloping than is the case with the upper part of the walls of the cwms ; in other words, the replacing of the débris on the upper part of these walls would make them

* Lacustrine waves, within so small an area, could not have rounded the larger stones which partly compose this drift. (See *Excursion VI.*)

overhang at a considerable angle.* I think it most probable that the greater and more firmly compacted part of the débris represents the general outscooping of the cwms, and that the moraine matter is superficial and super-deposited.

In Cwm-Llafar it is certain that the great deposit of stones and earth is marine, and that the effect of glacial agency has been principally to plough it out. This discovery (for which we are indebted to Professor Ramsay) strengthens the supposition that the main mass of débris in front of cwms and lake-basins is a marine drift.† On digging down we find it more or less rounded, while most of the looser blocks on the surface are angular, as if left by glaciers.

For further observations on the lake-basins and cwms of North Wales, I must refer the reader to *Excursions to Snowdon, Nant Francon, Carnedd Llevelyn, and Llyn Dulyn*. I shall now proceed very briefly to consider the various theories which might be advanced to account for the origin of lake-basins and cwms.

Theory of Nestling Glaciers.—It would be difficult to conjecture to what extent glaciers nestling in cwms may have modified their form. Admitting that glaciers may have ground out rock-basins in valleys, it seems very improbable that they could have formed approximately circular basins in those cwms where the lakes lie near the inner wall. In Cwm Dulyn, for instance,

* Supposing a glacier capable of undermining backwards, and, by a reflux action, of pushing the undermined matter forwards, so as to mix with the superficial matter carried forwards and dropped down in front of the cwms, the walls of the latter might retain their steepness. Few, however, would suppose a district or nestling glacier capable of performing such a feat.

† I think that the greater part of the débris in front of some, if not all lake-basins, would, on examination, be found to have come out of the basins or lower parts of the cwms.

the inner wall shoots right down into the lake, so that no glacier could have excavated the lake-basin without turning round or gyrating. It is true there is a considerable breadth of slope above the inner precipice of

Fig. 52.

Hypothetical Section of Cwm Bochlwyd (near Llyn Ogwen). A Summit of Glyder Bach. B Llyn Bochlwyd. C Marine drift. D Glacially-transported blocks, and moraine matter. E Screes.*

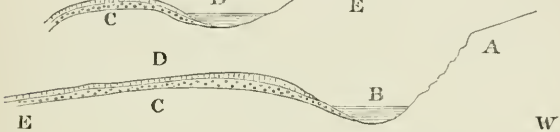


Fig. 53.

Hypothetical Section of Cwm Dulyn (NNE. of Carnedd Llewelyn). A Eastern slope of the ridge between Y Foel Frâs and Cefn yr Arryg. B Llyn Dulyn. C Large boulders partly rounded, and graduating into finer marine drift eastwards. D Glacially-transported large blocks.†

Cwm Dulyn, where a glacier may possibly have accumulated, and whence it may have fallen over the precipice (already existing), so as to act like a waterfall at its base. But in the case of Cwm Bochlwyd, no glacier could have accumulated on the narrow ridge of Glyder Bach, behind the inner wall. The same remark would apply to Cwm-y-Gader (Cader Idris), behind which there is a narrow ridge with a peak. Between Glas Llyn and the western boundary of the cwm (from which the

* For a particular description of Cwm Bochlwyd, see *Excursion from Bethesda to Nant Francon.*

† For a description of Cwm Dulyn, and remarks on drifts, see *Excursion from Conway to Llyn Dulyn.*

ground falls away) there is only a third of a mile where a glacier could have accumulated, and in the other cwms mentioned above (Cwm Dulyn excepted) the space is still less. The question then is, Could the part of the glacier behind the area of the lake-basin have exerted sufficient pressure on the part occupying that area to enable it to grind out the basin? or could any pressure from behind, or any movement forward, enable ice to grind out an approximately-circular lake-basin? It does not appear probable that deep lake-basins* (or lake-pits, as some of those in Wales may be called) could have been ground out of solid rock by the power of ice exerted within so narrow a compass; † but ice may have jostled the loose stones or previous outscoopings of a cwm ‡ into a hollow more or less cauldron-shaped. §

Theory of a Great Flow of Land-ice.—The power of a moving crust of land-ice several thousand feet thick to excavate cwm-shaped hollows does not seem to have

* The depth of Glas Llyn is probably one-sixth of its average diameter.

† It is quite true the depth of most of the cwms of Wales may have admitted of a sufficient thickness of ice to have exerted a downward pressure; but pressure from behind must have been necessary to give a scooping-power to the ice.

‡ Or the marine drift partly filling up cwms.

§ Since the above was written, the Rev. M. H. Close has kindly communicated some of his views on the excavation of lake-basins, in a letter from which the following are extracts :—'A corry-glacier must have been largely composed of snow, which was *drifted* into the hollow, and only partially of snow which fell into the catchment-basin. This gives us more snow to work with than we might have expected. It likewise, I think, gives the *forward* pressure you desiderate. The drifted snow would fall over the upper edge of the corry, and then down the precipice, without flying much out towards the middle of the corry. You have noticed a thing that had struck me when looking at the cwms in Kerry, namely, that the rock-basin is often evidently a part of the cwm; it is but the bottom of the scooped-out hollow.' A paper on Irish corries, by Mr. Close, will soon be read before the Royal Geological Society of Ireland, and may possibly be printed before this work is published. (Sept. 1868.)

received much consideration. It could only have done so on meeting with an obstruction, such as a steep slope, which would deflect the current of ice as currents of water are similarly deflected, and make it acquire a gyratory motion, enabling it to undermine semi-circularly backwards, and possibly at the same time downwards. One would suppose that ice under the influence of sufficient pressure from behind, might in this way simultaneously excavate both cwms and lake-basins.

Theory of Grounded Icebergs.—Supposing icebergs floated by marine currents to have been grounded, or rather to have become entangled in shallow depressions, they may have acquired a kind of motion which would have enabled them to hollow out a cwm or a lake-basin; so at least one might suppose, but too little is known of the submarine effects of icebergs to justify our speaking with confidence on this subject.*

Theory of Deflected and Eddying Oceanic Currents.—If we could suppose great oceanic currents to be possessed of sufficient excavating power, it would be easy to fancy them capable of hollowing out both cwms and lake-basins while in the act of eddying, gyrating, or being deflected by submarine slopes, escarpments, or banks. That they are capable of producing the *form* of the phenomena requiring explanation is evident from what we see of their effects on sand in estuaries.†

* 'In Baffin's Bay, Dr. Sutherland tells us, the icebergs tumble about and butt against each other in great confusion, like houses in an earthquake, and also occasionally assume a *rotatory* motion from the pressure of ice-floes against them. . . . If grounded, it would rock about by the action of the surf, and thus give rise to irregular curved markings.'—Jamieson (*Quart. Journ. Geol. Soc.* Feb. 26, 1862). Dr. Scoresby has stated that floating fields of ice frequently acquire a swift rotatory motion.

† That currents may have had something to do with the excavation of lake-basins would likewise appear from the existence of basin-shaped hollows among the undulations presented by the surface of the boulder-clays and

Theory of 'Waves of Translation.'—In 'waves of translation' we seem to have an agency possessed of both excavating power and a capacity to produce the form of the phenomena under consideration, including lake-basins. This can be illustrated by experiments with water and a heap of sand. Most geologists, at the present day, are disposed to discard the idea of waves of translation on a great scale having ever been a regular part of the economy of nature; but I agree with Sir R. I. Murchison, that the terraced aspect of the Welsh hills is a proof of sudden elevations or depressions of the sea-bed alternating with periods of gradual movement or of rest; and that rushes of water of greater or less force must have resulted from the submarine convulsions; and I agree with the same eminent authority in believing that cleanly-swept depressions, whether 'valleys of elevation' or cwms,* indicate the *maximum* force of the débâcle.

Origin of Cwms irrespectively of Lake-basins.—I have already shown (see *Escarpments, &c., of Snowdon*) that rain is incapable of giving rise to the transverse outline of cwms, or of converting convex into concave surfaces. Let us now see whether the ground plan of cwms can be explained by the action of rain.

Theory of Rain.—To be able to judge of the effects of

gravels of Furness, South Lancashire, and elsewhere. These hollows must have been produced by denudation, because the surrounding knolls often consist of at least two kinds of drift, without any indication at the surface, and because beds of sand and gravel do not dip towards them. They generally contain swamps, or are occupied by temporary tarns, where there are no artificial cuttings to let the water escape. As their bottoms and sides (near Blackpool, for instance) often consist of *upper* boulder-clay, they could not have been formed by a great flow of land-ice; and oceanic currents, acting at a moderate depth, would seem to be the only agency to which they can be referred.

* Many cwms contain no trace of the denuding agent, excepting a little moraine matter and recent screes.

rain we must examine what rain is now doing in cwms, and what rain is doing on surfaces similar to those in which cwms have been excavated. In cwms, rain is not tending to develop their typical or characteristic form. To be a cwm, a hollow must be approximately curvilinear. Rain is doing all it can to destroy this curvilinearity. On hard rocks, as already remarked, its action is powerless until it has collected a little loose matter and become concentrated into a streamlet. Rain-streamlets in cwms to which the ground inclines, are gullying their brims, and in all cwms channelling their sides. A continuance of the process would render a cwm a mere confluence of ravines. The chipping action of frost, aided by rain, is tending to reduce the steepness of the encircling cliffs by bevelling off their upper parts, and hiding their bases under screes. A delta of screes is generally found under a rain-channel. Rain in a state of dispersion is possessed of so little power that it cannot keep up a uniform abrasion of the sides of cwms so as to preserve their curvilinearity. The area of cwms is generally large enough to contain springs, and collect rain-water, so as to form small streams towards their outlet; and the insertion of these streams in the Ordnance Map, makes cwms appear as if they had been furrowed out by water running downwards. But in the absence of evidences to the contrary, these streams may as reasonably be regarded as the effects rather than the causes of cwms.

Theory of Retrogressive Streams.—Let us now see what streams are doing on surfaces similar to those on which cwms have been superimposed. A single stream on an escarpment or gradual slope produces a ravine. It may be abruptly terminated at its inner end, and the stream may excavate backwards by means of a cascade. But it is, after all, a ravine, narrowing towards the bottom. If a single stream cannot produce a cwm, several streams cannot combine so as to give rise to a cwm. On the east side of Nant Francon, not very far from the Penrhyn slate quarries, three streams (if I remember rightly) on a steep slope, unite, and something like an incipient cwm at first sight seems to be the result. But a little reflection shows that it is a resemblance limited to an early stage in the united action of the streams. A continuance of the retrogressive excavation will merely deepen and widen each channel. On the hill-side above Soutergate, Furness, Lancashire, two rapid streams have excavated deep channels in boulder drift. Where they unite, there is a sharp separating ridge. This ridge has receded and will continue to recede as the channels of the streams become deepened and widened, but can never become replaced by a cwm.*

Theory of Springs.—In endeavouring to account for cwms, subaërialists would probably lay the main stress on springs. On many slopes in Wales a somewhat regular depression may be seen where a spring issues from the ground. The vegetation nourished by the spring water, appears to have sunk as if an abstraction of matter had taken place underneath. Supposing spring-water, aided by humus, capable of dissolving certain kinds of rocks, and carrying away the sediment (though it is far from being certain that among rocks where cwms most abound, springs are generally possessed of this power), the process would be incapable of undermining laterally so as to leave a hollow at all

* That streams have not excavated cwms may be inferred from the fact that streams after leaving cwms with increased volume, run down transversely-level slopes without being able to make channels beyond a few feet in depth. Could such streams have scooped out cauldrons from 500 to 1,000 feet in depth, and from half a mile to a mile in breadth?

approaching the breadth of an average cwm, while a spring undermining backwards, would leave a ravine, not a cwm.*

Theory of Sea-coast Action.—That the sea has been among the cwms of North Wales has already been shown. It has left undoubted marine drift in some of the cwms, and must have undermined their cliffs and rendered them more precipitous. Some cwms, like Cwm-y-Gader, may have been scooped out entirely by sea-coast action (the lake-basin, supposing it to be a rock-basin, excepted). In the case of the majority of cwms, it is more a question of modification than original excavation. We ought not, however, to forget that during a gradual rise of the land, the sea may have given rise to phenomena differing from those produced at a stationary level (cwms with sloping floors, for instance); neither ought we to overlook the fact that the sea, even at a stationary level, is very partial—that it makes cliffs in some places and leaves intermediate areas cliffless. Before sea-coast agency, as one of the main causes of the excavation of cwms is rejected, I think it would be well to take the trouble to examine what the sea is now doing among groups of islands similar to the hills of Wales and the Lake District at the time of their partial submergence. That the action of the sea in one shape or another, ordinary or extraordinary, or in connection with ice, has had much to do with the origin

* After recently studying the positions of springs, and the direction of streams in the cwms of the Coniston Fells, I have become convinced that both springs and streams are the effect instead of the cause of cwms. The excavation of cwms has developed springs, and furnished declivities for the channels of streams. The springs exist in what may be called accidental positions, and the streams run in accidental directions (see *Excursions from Coniston*). Springs, whether on the summits of hills (Helvellyn, Snowdon, &c.) on the sides or at the heads of valleys, or in cwms, have no connection with the form of the neighbouring ground.

of cwms, and that rains and streams have had very little, will I think appear from

Concluding Facts and Considerations bearing on the Origin of Cwms.—Cwms appear to have been imposed on a previously-existing land-surface, the shape of which could scarcely have been left so totally distinct from the shape of the cwms by an agency, such as rain, simultaneously acting on both, in however different a degree; in other words, cwms *appear* to have been formed by a sweeping agency assailing slopes laterally, not vertically, and infringing on the previous form of the ground. The sea at a different level, and by a different sub-agency, can infringe on a form of ground it has itself produced. Wave-action at one level can infringe on ground formed by wave-action, during previous gradual elevation or depression, or on ground possibly formed by currents; but rain can only perpetuate the same form of ground, and the limit of its versatility of action cannot exceed an exaggeration or mitigation. Cwms obey no general rule (taking different districts in connection) as regards denudability of rocks arising from composition or structure. They occur in the most unlikely, as well as likely situations. In North Wales, where they are most typically developed, they show a preference for zones of alternate sedimentary and interbedded or intruded igneous rocks; sometimes the igneous rocks have been scooped out, sometimes both igneous and aqueous, sometimes aqueous. They have often been scooped out of shales, slates, grits, and other rocks least amenable to the chemical action of rain; whilst in mountain limestone (believed to be the most susceptible of pluvial decomposition) they seldom occur. The walls of cwms, excepting where they run partly along faults, are often of the same nature with the rocks which have been removed. The dip of the beds or laminæ resulting from deposition, jointage, or cleavage, exhibit all angles in cwms; they dip away from, towards, or obliquely along the face of the bounding cliffs or slopes. This must be the case, seeing that cwms generally embrace more than half a circle.* But it is likewise true that the beds forming the inner walls of cwms dip in different directions in different instances, and often in the same cwm. In the Lake District, cwms differ from those of Wales in showing no greater preference for the volcanic, than for the pre-volcanic or Skiddaw Slate area. In the igneous area of Dartmoor, there are no cwms, so far as I am aware. The metamorphic and igneous rocks of the Malvern Hills have been hollowed out into some of the most curvilinear cwms in South Britain. In the cretaceous districts there are cwms in the greensand as well as chalk, though in the oolitic districts they principally occur in calcareous rocks. Professor Ramsay says that cwms or corries 'are the result of denudation, and are intimately related to the icy phenomena of a very late period, and indeed in all glacier regions, past and present, high circular hollows like these are exceedingly characteristic.' ('Geological Survey Memoir on North Wales.')

Origin of Edges.—In addition to what has been said concerning the origin of edges separating cwms, I would here direct attention to the varying shape of many sea-coast headlands, which both rise and fall seawards, are both smooth and serrated, continuous and wrecked, gradually and abruptly terminated. Sharply-ridged headlands are not uncommon on the coasts of Ireland (see *Introduction*) and on all fully-exposed sea-coasts. They are the effect of the warfare of billows acting in nearly opposite directions, and they represent stages in the process of mutual encroachment after the

* If partly filled with water, few cwms would appear to embrace more than one-third of a circle.

last lingering strip of table-land, or gradually swelling mountain, has disappeared.

NOTE.—Since writing the above, I have reperused * Professor Ramsay's 'Old Glaciers of Switzerland and North Wales,' and find that he fully admits the action of the sea, in terracing and modifying the surface of Snowdonia, and in leaving great moors of marine boulder drift, stretching up into cwms. He likewise believes that this drift is often angular, like moraine matter; that some lake-basins were formed on sea-coasts; that a beach of marine boulder drift sloped smoothly up towards the coast; that a coast-glacier occupied a cwm, pushed out to sea, shed a moraine between the cwm and the sea-beach, if not over the latter, and that this moraine afterwards dammed up the lake, filling the hollow which had been kept clear for it by the glacier. He instances Llyn Dulyn; but the question remains, by what agency was Cwm Dulyn scooped out (see *Excursion from Conway to Llyn Dulyn.*) May not a glacier filling a shallow depression on the sea-coast—a depression little more than a variation of a generally-undulating surface—have, in part or in whole, become an iceberg? and may not the iceberg, in the act of becoming launched, have received a verticose, or approximately verticose motion, from currents or waves by which the cwm and lake-basin were both in course of time excavated? There are no traces, in the shape of erratic blocks, of icebergs from a distance having grounded on the Welsh hills; but I think the true explanation of the origin of many cwms will ultimately be found in some kind of action midway between glacial and marine.

* I thought it best to read comparatively little *before* visiting Snowdonia, and I believe it is the practice of the ablest geological surveyors to read principally after and not before traversing a district.

CHAPTER XI.

REMARKS ON DETACHED AND CONICAL HILLS.

As detached and conical hills are about the most universally-admired forms of surface-configuration, I have prepared the following list of eminences in England and Wales which agree in being wholly, or in a great measure detached from other hills; which are conical from one, several, or all points of view; two, three, or all sides of which are steep, and the height of which is considerable in proportion to their breadth. Their petrological composition, so far as certainly known, is added:—

The Sugar Loaf, near Abergavenny: old red sandstone. Viewed from the east, it is a perfect cone, tapering finely to a point at a high angle. Viewed from the south, it is a truncated cone.

The hills called Hanter and Worsel (igneous rock, syenite, and greenstone) figured in Sir R. I. Murchison's 'Siluria,' p. 109.

Caer Caradoc, near Church Stretton, Shropshire: erupted trap.

The Wrekin, near Wellington, Shropshire: pinkish felstone, vesicular lava, various kinds of trap, &c.

Pontesbury Hill, near Pontesbury, Shropshire: erupted trap.

Corndon Hill, near Cherbury, Shropshire: erupted trap.

The Breidden Hills, on the borders of Shropshire and Montgomeryshire; porphyritic and amygdaloidal greenstone, with contemporaneous volcanic breccia. A sketch of these hills as seen from Powis Castle may be found in 'Siluria.' The following is a sketch, as seen from a hill near Newtown. Rodney's Pillar, on the left,

Fig. 54.

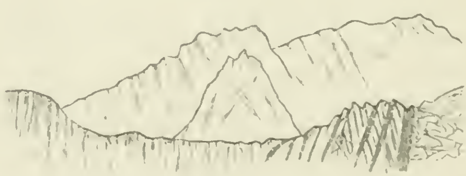
The Breidden Hills—Moel-y-Golfa towards the right.

is the highest, though it does not appear so in this sketch.

Castle Dinas Bran, near Llangollen: Wenlock shale. This is perhaps the steepest conical mountain on all sides in South Britain, though its height is not very great.

The Tryfan Mountain, near the head of Nant Francon. Seen endwise, its two sides are steeper than those of any other mountain in South Britain.

Fig. 55.



Tryfan Mountain (near Centre of Sketch) from the N.E.

Yr Eifl, or Rival Mountains, SW. of Carnarvon; porphyritic syenite, felspathic porphyry with or without agates, and greenstone.

The Western Langdale Pike, or Pike o'Stickle, Lake

District. It is, I believe, a nearly perfect cone from all points of view.

Catchedecam, or Catstye Cam, Helvellyn ; a very fine conical mountain rising from Swirrel Edge, NE. of the highest point of Helvellyn. As seen from Ulleswater on the NE. looking up, and from the summit of Skiddaw on the NW. looking down, it presents a very imposing aspect.

Causey Pike, one of the Cat Bells, and other eminences as seen from the neighbourhood of Keswick. None of them are, strictly speaking, cones.

Castle Crag, Borrowdale, a very striking detached hill.

The Haycock, &c., to the south of Ennerdale Water.

Red Pike, between Ennerdale and Buttermere.

Many other instances of more or less detached and conical hills in the Lake District, and elsewhere in South Britain, might be mentioned. Those of them which are intruded igneous rocks present indications of their having been at least partly buried under stratified rocks thrust up by them or deposited upon them ; these stratified rocks having subsequently been denuded.

CHAPTER XII.

ORIGIN OF TABLE-LANDS AND PLAINS.

This subject has been slightly referred to in the chapters on escarpments. Taking it as a whole, its consideration is perhaps as much beset with difficulties as any other department of surface-geology. So far as a plain produced by deposition on a tidal zone is concerned, it is easy to conceive of such a surface finding its way to any altitude during a uniform elevation of the land above the sea. Plains of deposition may enlarge in breadth along sea-coasts, as is now the case on the north side of Morecambe Bay, and the south-east coast of the Bristol Channel, &c., while the sea remains at an almost stationary level. They are the seaward extension of barriers formed by the sea. Away from coasts deep depressions may become filled up. though we have no reason to suppose that the depositing action of currents apart from waves, tends to produce a level surface. As would appear from soundings, currents, as depositing agents, either conform more or less to the inequalities of the previously-denuded surface, or introduce new inequalities. In estuaries, or confined seas, these inequalities may be comparatively small. The eskers of Ireland, and the ridges and knolls of some parts of the New Forest, may represent their magnitude. But on wide submarine areas, the inequalities resulting from deposition must often be considerable. In deep seas, beneath the sphere of currents, the surfaces of deposition may be approximately level where uniform precipitation is taking place.

Denudation of Table-lands.—As we have no evidence, in any case, of the table-lands of England and Wales being upheaved original surfaces of deposition (however much they may often conform to these surfaces), while, in most cases, we have evidence to the contrary, all table-lands may be considered as the effects of denudation. It is true that many, if not most, table-lands, are covered, more or less, with some kind of drift which fills up previously-existing hollows. For instance, on Black Down, near Taunton, grooves and troughs are often filled up, as already noticed (see *Escarpments*). But these depressions are of so trifling a depth that the question remains, how were the table-lands planed down? We know of only one denuding agency which, on a large scale, is capable of planing down rock-surfaces horizontally, namely, sea-waves. At a stationary level, waves may wear back coasts, and produce no greater inequalities than those limited by the vertical distance between the highest and lowest tidal-levels. This planing agency may attack an island, and render its surface flat—a group of islands, and convert them into a series of flat areas, with passes between, or plane them down into one great flat area. Here and there circumdenudated knolls and peaks may be left. The sudden elevation of the bed of the sea would convert these islands and groups of islands into table-lands. But a gradual elevation, after a long pause, would round off the edges of the table-lands, and give them more or less of the shape of flattened domes. In this way most of the phenomena connected with table-lands may be explained. That an elevated table-land, surrounded by lower ground, could not have originated in the planing back of the shores of continents, will appear when we reflect on the improbability of the original surface having retained its flatness during the long periods required to wear down the higher ground by which it was at first bounded, to a level lower than itself.

The Black Down Table-lands.—Most large table-lands are divided into smaller ones by shallow passes. The streams which often run between the sub-table-lands, have taken advantage of the passes, superimposed their channels on them, and in many places deepened them. This would appear to have been the case in the great table-land, the divided parts of which are called the Black Downs, in the SW. of England. In most places these parts, or minor table-lands, have flat summits, excepting where they smoothly curve down into the passes. Their outer boundaries are generally marked by abruptly-commencing escarpments, which sometimes run for considerable distances along the sides of the passes (see *Escarpments of the Black Downs*). Were the passes scooped out by currents before the minor

Fig. 56.

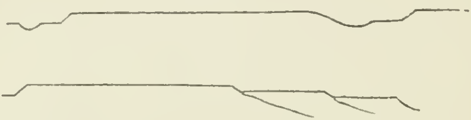


Table-lands, Passes, and Escarpmental Boundaries of the Black Downs.

table-lands were planed down? or were the passes not scooped out until after the planing down of the great table-land? These are questions not so easily answered as one might at first suppose, and the mode in which the superficial drifts occur in various situations seems to complicate rather than to simplify the subject.

Table-lands of Haldon.—Great Haldon longitudinally, and for a considerable breadth transversely, presents a perfectly level line, as seen from a distance, and a flat surface when viewed on the spot. Little Haldon (as already hinted) is an instance of a table-land gently and uniformly curved transversely, and level longitudinally.

Table-land of East Dartmoor.—Between the deep valley which runs from Moreton-Hampstead to Bovey Tracey, and the valley of the Teign, there is a little known table-land with a series of shallow passes which have been deepened by streams. It consists of granite, and carboniferous (?) slate, with trappean protrusions. In many places its surface is very level, in others so smoothly rounded as to suggest the idea of glacial action. (See *Blackenstone Rock.*)

Table-land of Brendon Hill.—The term *undulating* *table-lands* may be applied to some of the elevated districts of North Devon and West Somerset. From Raleigh's Cross, on Brendon Hill, a considerable expanse of level ground, with dividing passes, stretches east and west, at a great altitude above the sea. It has been planed down in slate rocks with quartz veins and lodes of hæmatitic iron ore. The cleavage-dip is towards the south at a high angle. Farther westwards, in the direction of the irregular Exmoor table-lands, there are numbers of circumdenudated hills which (to use the words of Mr. Morgan Morgans, of Raleigh's Cross), exactly resemble so many inverted tea-cups.*

Table-lands of the Mendips.—There is a fine specimen of a small table-land, called Weorle Hill, close to Weston-super-Mare. Its summit, which is slightly covered with red loam, is wonderfully level for a distance of several miles in length, and about a mile in breadth. It is bounded on all sides by an escarpment, and presents an unusually striking appearance, on account of the plain of Scrobicularia-mud surrounding its base being parallel to the plain on its summit. Several parts of the Mendip Hills present table-lands at different levels. One of the most instructive I have yet seen lies between Shuteshelve and Longbottom passes. It is traversed both longitudinally and transversely by shallow passes, and curves gradually down towards the south, while, on the north side, it terminates abruptly in the escarpment already described (see *Escarpments of the Mendip Hills*). At a higher level, to the NE., the table-land, called Black Down, forms one of the remaining

* Circumdenudated small hills often occupy situations where they would appear to be projecting parts of table-lands or plains. They are precisely what would result from an agency simultaneously encroaching on them all round. They may be regarded as monuments left to point out where the planing-down action of the sea became locally limited.

portions of the old red sandstone nucleus of the Mendip range.

Salisbury Plain.—This well-known large table-land, though in many places flat, is more or less undulating and traversed by passes. On the north-western or Westbury side, it terminates in the escarpment already described (see *Chalk Escarpments of Hants and Wilts*), beneath which there is a parallel plain, at a considerably lower level than the table-land. I have heard it asserted that a great part of the average level of Salisbury Plain is so uniform that attempts have been made to render it illustrative of the rotundity of the earth (see *Marine Origin of Plains, &c.*). In many other parts of the chalk districts there are table-lands of greater or lesser extent. Whole ridges may be regarded as narrow table-lands, transversely level or curved, while longitudinally, for great distances, they often present a line so straight that, on a scale of six inches to the mile, a ruler would be required to represent their horizontality on paper. This may be seen on travelling along the lines of railway between Salisbury and Yeovil, between Didcot and Swindon, &c.

Cotswold Table-lands.—Many parts of the Cotswolds, above the great NW. and N. escarpments, are approximately level, and present horizontal lines, when seen from a distance. On the surface, where sections have been exposed, a considerable thickness of angular drift may here and there be seen. The fragments, though of local origin, have been arranged in such a way as to show that they have not of themselves started up from the rock below, but have been driven along by a cause more powerful than frost or rain.

Table-land of the Black Mountain.—This old red sandstone table-land (already noticed) is, like many others, a wreck in transverse section, for it is deeply furrowed in a SSE. direction by stream-valleys. How far the present streams have excavated the valleys, or how far the valleys show indications of the upper parts of their sides being continuations of an original transversely undulating surface, I have not had an opportunity of ascertaining. The north-west part of this table-land has retained its transverse horizontality.

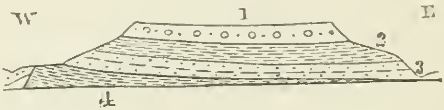
Table-lands of Wales.—The greater part of the above table-land is in Wales. In the carboniferous districts to the SW., there are many table-lands, horizontal, inclined, wide, and narrow. Here as elsewhere they often form moorlands more or less swampy or boggy. In the Silurian districts of Wales, the table-lands are generally narrow, and, in most places, must be regarded as wrecks of former extensive plateaux, or dome-shaped mountain masses. They are frequently covered, and their original undulations partly levelled by accumulations of marine drift. The elevated area between Minera and Llangollen exhibits alternations of bog, and drift consisting of fine rounded shingle.

Table-land of the Peak.—The highest and most remarkable large table-land in South Britain is the Peak Mountain, in Derbyshire, which reaches an elevation of 2,000 feet above the sea. 'Its upper surface is somewhat uneven, and is entirely composed of the millstone grit, which, for the most part, is buried under a thick coating of peat, fissured into innumerable gullies and clefts, which cause an excursion across a surface which on the map [in the section] appears a plain, to be in reality a succession of dips and emersions.'* (See *Millstone Grit Escarpments.*) The section, (Fig. 57), copied from Messrs. Hull and Green's article (p. 251), will give a good idea of the structure of the Peak table-land.

* Messrs. Hull and Green, *Quart. Journ. Geol. Soc.*, March 23, 1864.

The principal streams have their sources on the table-land, flow across the escarpments, and down the slopes which stretch away from the base of the escarpments, in a manner indicating that the escarpments were formed independently of the action of the streams.*

Fig. 57.



1. Kinder Scout, or Fourth Millstone Grit. 2. Upper Yoredale Shale. 3. Yoredale Grit. 4. Lower Shale.

Table-lands of the Lake District.—The Lake District may be regarded as a country of ancient table-lands and dome-shaped areas, which have been wrecked to such an extent that there is now a greater deviation from a horizontal line within a given space than can perhaps be found in any other country in Europe. It is this peculiarity that forms the principal attraction of the district, and gives it a rank (so far as scenery is to be estimated by abrupt succession) superior to Scotland, Ireland, Wales, or the Alps. Among the few elevated flat surfaces in the Lake District, and some of these are more or less inclined, may be mentioned the summits of Saddleback, Helvellyn, Fairfield, the plateau above Wallow Crag (near Keswick), the summit of Grassmoor, &c. Among the most extensive irregular table-lands may be mentioned the elevated track between Thirlmere and Watenlath. On the eastern border of the Lake District, there is a remarkable table-land terminated on the east by Cautley Crag.

Intermediate Plains.—Between table-lands surrounded

* There are many other millstone-grit table-lands in the north of England. (See *Escarpments.*)

by falling ground and plains surrounded by rising ground, there are many instances of steps or broad terrace-shaped plateaux. In England and Wales these are generally ill-defined, their original uniformity having been broken up by the action of streams. This might be expected, as they are situated at those intermediate levels where the excavating power of streams is the greatest. Traces of them may be found in many parts of Wales (see *Excursions*).

Lowland Plains.—Plains at a low level derive their flatness, to a greater extent than table-lands, from deposition. But, generally speaking, it will be found that their flatness is likewise mainly owing to denudation. Lowland plains, like table-lands, are seldom quite horizontal in every direction. Excepting where they have retained the character of marsh-lands, they incline at a very low angle in one direction, which, on inspection, I believe will generally be found to be towards the present or former bed of the sea. Supposing an original horizontality in every direction, their upheaval above the sea would be likely to give them a slight sea-ward inclination. But it is probable that plains were denuded by the sea wearing back its cliffs, during an exceedingly slow and gradual depression of the land; for in this way the process of wearing back would be more likely to form a surface equivalent to the breadth of many plains than it would be with the land remaining at a stationary level. During a gradual rise of the land a uniformly inclined plain would only result where the rate of upward movement corresponded to the levelling power of the sea.*

Origin of Lowland Plains.—It seems strange that some geologists should not only admit, but lay great

* The Rev. Maxwell H. Close informs me that the great central plain of Ireland dips in a westerly direction.

stress on the marine denudation of upland plains or table-lands, and yet deny the marine origin of many lowland plains. Their theory is, that rain has formed those lowland plains which are bounded by ridges or escarpments, such as the plains of the Weald of Sussex and Kent (according to Col. Greenwood, Dr. Foster, Mr. Topley, Mr. Whitaker, &c.); the plain of Yorkshire (according to Mr. Topley); the central plain of Ireland (according to Professor Jukes); and all small land-locked plains (according to most subaërialists). I have already referred to the incapacity of rain to make plains (see *Escarpments of the Weald*), and shall again refer to it under the head *Action of Rain*. Here I would only observe that, allowing rain to be capable of lowering a previously level surface by its chemical action on rocks of uniform composition, such as chalk, it would not follow that the mechanical action of rain, which can only be effective when *linearly* concentrated, is adequate to the formation of extensive flat areas, and far less would it follow that rain-streamlets are able to plane down the upturned edges of strata, over an area many miles in extent. A stream can only erode rocks while its channel retains a certain degree of inclination. An erosion-conferring degree of inclination causes a stream to deepen more than widen its channel. When the inclination becomes so small that the stream begins to widen, deposition takes the place of erosion to such an extent that the stream winds about in a bed formed of its own alluvium. Frost, rain, and gravitation, may widen the channel of a stream, in proportion to the incoherency of its rocky sides, but only by producing sloping, not flat surfaces. A river may wander over a previously-existing plain—play with its marine drifts, and even leave fluviatile shells imbedded; it may here and there wear back, for a limited distance, an escarpment; but all this is distinct from systematically making a plain.

Marine Origin of Plains proved by their coincidence with the Convexity of the Globe.—Many plains are so flat, that on a scale of one inch to a mile they require to be represented on paper with the assistance of a ruler, and on a scale of six inches to a mile some plains present very slight deviations from a straight line. This is the case with the Weald clay plains of Kent and Sussex, and still more so with large portions of the Plain of Cheshire and Shropshire, the Plain of York, &c.; not to mention those plains of Somersetshire which can scarcely yet be said to have finally emerged from the sea. The above and other areas maintain *a slightly-varying average level above the sea* for distances varying from two or three miles to at least nine or ten miles, and in some instances, an average level above the sea, with no great variation, for a distance of at least twenty miles. Their surfaces must therefore conform to the convexity of the earth, and no one would assert that rain could have given rise to such a coincidence, or that it can be explained by any agency excepting that of an enveloping fluid, shaping the submerged land in conformity to the figure of its own surface. This argument for the marine origin of plains is not weakened by the fact that most plains incline very gently to one point of the compass. At right angles to this direction, their convexity I believe would be found parallel and equal to that of the sea. In other directions their convexity would be found to be *equal* though not parallel to that of the sea. But where are we to set a limit to the application of this argument? If the marine origin of extensive flat surfaces can in this way be proved, what reason have we for supposing that flat surfaces too small to exhibit a satisfactory amount of convexity have not been formed by the sea? What reason have we for assuming that the flat bottoms of many valleys (not caused by deposition during river-floods) have not been planed down by the sea? It would be very interesting to inquire how far the bottoms of valleys either flat or ⌣-shaped transversely, partake of a longitudinal curvature equivalent to the convexity of the sea, as this would tend to show how far these valleys have been denuded by the sea. With regard to the bearing of the present argument on the origin of escarpments, it may be remarked that the convexity under consideration is continued to the base of many escarpments by which plains are bounded, and the lower parts, at least, of these escarpments must therefore have been acted on by the sea.

Principal Plains of England and Wales.—Among these, attention may be directed to the Weald clay and gault plains under the greensand ridges and escarpments of Kent, Sussex, and Buckinghamshire, &c.; the tertiary plains of the S. of Hampshire, SW. of Sussex, and various parts of the London Basin; the Vale of Blackmore, Dorsetshire; the Vale to the north of Exeter, partly watered by the Culm, with its island-like knolls; the plains in the neighbourhood of Bridgewater, Weston-super-Mare, and Clevedon, Somerset; the plain of Gloucester and Worcester; the plain between Wolverhampton and Stafford; the great plain of Cheshire and Shropshire; the plain of Leicestershire with its desiccated archipelago called Charnwood Forest; the plain of Nottinghamshire and Lincolnshire partly watered by the Trent;* the great plain of Yorkshire, which seldom rises more than 100 feet above the sea; the plain of Carlisle, &c. In Wales there are many flat-bottomed valleys, and a few considerable-sized plains. Among

* To the south of Newark this plain is very flat and richly cultivated.

the latter may be mentioned the Vale of the Ithon, near Builth, the Vale of Clwyd, the northern part of which is extremely flat, &c.*

CHAPTER XIII.

CLASSIFICATION AND ORIGIN OF VALLEYS.

Those depressions of the earth's surface which are much longer than broad, and which are distinct from open plains on the one hand and cwm-shaped recesses on the other, may conveniently be considered under the name of valleys. Before proceeding to describe their various forms and combinations, it may be well to inquire how far the action of waves on coasts, and currents at a distance from coasts, are capable of excavating valleys.

Valleys formed by Sea-coast Action.—So far as our actual knowledge extends, sea-coast action is now principally widening previously-existing valleys or *depressed* land-surfaces to a lesser or greater extent, in some cases perhaps exceeding the amount of the original excavation. Where fresh valleys, in the shape of creeks, are formed by the sea on the shores of the British Empire, we have no satisfactory evidence that they exceed half-a-mile, or at most a mile in length; but this may be the size they have attained since the close of the glacial submergence, and since the present relative level of land and sea (subject only to minor oscillations) became established. Still, I believe we are not to look to sea-coast action at

* This level part extends to the base of the limestone escarpments, and these escarpments, especially near Abergele, curve round and run up the sides of the lateral valleys in such a way as to show the identity of the cause which denuded the plain and the mouths of the valleys.

a stationary, or nearly stationary level, as furnishing the main explanation of most of the valleys of England and Wales. We ought not, however, to leave out of consideration what would necessarily take place during the rising and falling of a previously-existing mountain-declivity above and beneath the sea-level. Suppose a steep slope running to a great depth under the sea, and that, at a stationary level, it is shaped into capes and coves. As the land gradually rises a cove will be gradually continued down the face of the slope so as to form a valley, and the cape will be continued downwards in the shape of a ridge.* To insure the formation of a continuous and regular valley, it would be necessary that the lithological or other conditions, which at the outset gave rise to the cove and cape, should be continued downwards; and this would generally be the case if not in straight, at least in sinuous lines, so that winding, if not straight valleys, would be formed. It is true, that unless the rise and fall were very slow, the depth of the valley would not be nearly so great as the depth of the original cove; but still a valley would be the result. It may farther be observed that an upward movement of the land might expose dissimilar strata at different levels, which would be unequally acted on by the waves so as to form shallow longitudinal valleys which would give an irregularly terraced aspect to the slope. The lithological structure of a slope might vary so as to cause valleys to cross each other during the rise of the land, or it might be adapted only to give rise to parallel valleys. In no case could a uniformly-inclined plain be the result, unless the strata happened to be very uniform in their

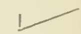
* This I have seen illustrated in Conway estuary; where, as the tide sinks, the small wind waves continue the excavation of a miniature cove downwards, so as to leave a ⌣-shaped depression in the sand, sloping longitudinally, and sometimes terraced.

structure and composition. In this way, I think it must be admitted that a large proportion of the *shallow* valleys which diversify the slopes of mountains in England and Wales, have been produced. Instances will be noticed in the sequel.

Valleys formed by Currents.—In addition to what has been stated under the head *Denuding Action of Tidal Currents,* I would here observe that if tidal currents in estuaries are capable of denuding to a certain extent, currents in moderately deep seas may be possessed of greater power. If it be true that the denuding power of a river is in proportion to the depth of water (the velocity being the same), it seems reasonable to suppose that a current several hundred feet deep should be possessed of greater excavating power than a shallow estuarine current of equal rapidity. It has never yet been disproved that oceanic currents, including the long-continued action of tidal currents and great oceanic rivers, such as the Gulf Stream, and the sweeping action of currents caused by sudden upheavals or depressions of the sea-bed, are capable of scooping out valleys, while we know of no other agency which can offer anything like an adequate explanation of the immense number of  and -shaped valleys which in many parts of England and Wales are crowded within so small a compass as to be glaringly disproportionate to the accompanying amount of watershed. Long-continued subaërial action, erroneously called *time,* will excavate a ravine to any depth compatible with inclination of channel, but it will not explain the crowding of so great a number of valleys within so small an area.* The power of rapid tidal currents to excavate straits

* If the amount of atmospheric precipitation be equal to the excavation of all valleys, how is it that the vast majority of valleys are nearly dry?

in archipelagoes (which straits become passes) is admitted by all, including the extreme subaërialist, Professor Jukes;* and if we must acknowledge the inferior power of currents of equal depth in less confined situations, and with less velocity, we must still admit that all currents, as denuding agents, have the advantage over rivers in their being able to excavate on *level ground*, if not up an acclivity, and in their being possessed of a *volume of water proportioned in breadth* to the size of the excavation.

Longitudinal Valleys.—In every part of the world we find valleys of the transverse shape of , , or , which run more or less parallel to ridges, escarpments, and long and narrow table-lands. They may be called longitudinal valleys to distinguish them from transverse valleys, or valleys which cut across ridges, escarpments, or table-lands, or run down their slopes. As regards their general contour, longitudinal valleys may be divided into several kinds—those more or less open at one end, those partly open at both ends, and those closed at both ends. These kinds graduate into each other. Excepting some of those which are quite open at one end (when quite open at both ends they come under the denomination of passes), they are generally connected by transverse gorges or outlets with other longitudinal valleys, or with plains. Longitudinal valleys may be very elongated, or they may be mere basins or valley-expansions connected by transverse gorges. Transverse gorges may likewise connect regular plains, or irregular areas lying lower than the summits of the intervening ridges or table-lands through which the transverse gorges have been excavated.

Instances in England and Wales of Longitudinal Valleys,

* 'On the River-Valleys of the South of Ireland,' *Quart. Journ. Geol. Soc.* July 18, 1862.

Valley-Expansions, Basins, and Plains connected by Transverse Gorges.—Beginning with Devonshire in the SW., I would refer to three remarkable instances described by Sir H. De la Beche.* (1.) Near Kit Hill (1,667 feet above the sea) the River Tamar runs through ground (Devonian slate) higher than that in which it takes its rise (carbonaceous rocks). (2.) The Exe, after draining an area with a general descent, cuts through higher ground near Silverton (carbonaceous rocks). (3.) There is a basin in North Devon called Merton and Berry Moors, which would be a lake if the valley or outlet-gorge between Merton and Huish were stopped up. There are many other instances in West and North Devon. In East Devon the River Dart (tidal $10\frac{1}{2}$ miles inland), when viewed from a hill at Sharpham, presents the aspect of ten distinct sheets of water, apparently isolated, arising from a succession of basins and connecting channels. Near Greenway woods, where the river is narrow, a rock called Anchor Stone is visible at low water, with a depth of more than sixty feet around it. The great local variations in the depth of the tidal part of the river could not have been produced by the action of a former fresh-water stream, supposing the valley of the Dart to be a submerged land-valley, as Professor Playfair supposed.† West of Ashburton the fresh-water stream of the Dart runs along the bottom of a deep basin, and escapes through a narrow ravine. In the neighbourhood of St. Mary Church, near Torquay, there is an instance of an irregular open depression, the drainage of which (very trifling) escapes through a narrow and deep limestone

* *Report on the Geology of Devon and Cornwall.*

† Were the channel of the estuary of the Dart to become upheaved, it would probably be a string of lakes. How far any or all of these lakes would be situated in rock-basins would be an interesting inquiry.

gorge in the direction of Torquay. On the south side of a tributary gorge (at Upton) there is a wonderful natural limestone arch with a perforated summit and lithodomized sides, which is as obviously the work of the sea as any arch now in course of being formed on sea-coasts. Its existence shows that the sea must once have occupied and modified the limestone gorges of the district, if they were not altogether excavated by its waves and currents. The depression called the Bovey Basin, including the valley running in the direction of Torquay (lower Miocene clay and lignite) may be regarded as a longitudinal valley, the outlet of which is the estuary of the Teign, which could not have been excavated by the fresh-water river Teign, as is evident from a comparison of former and existing levels, taken in connection with sections of different parts of the district. Near Chudleigh there is one of the most remarkable denudational phenomena in South Britain. A small brook flows under a limestone escarpment with an open area to the west (carboniferous (?) slate) which graduates downwards into the wide valley of the Teign. The brook then flows along a narrow gorge, called Chudleigh Glen, which cuts suddenly through a projecting tongue of limestone. The trumpet-shaped southern opening of the gorge has been caverned and otherwise marked by sea-waves, and on the summit of the overhanging cliffs rising from beneath the vegetable soil, I have seen smoothed, rounded, hollowed, and perforated rock-surfaces, testifying to the former presence of the sea. To the NNE. of Exeter there is the plain of the Culm (see *Plains*), which contracts into a narrow gorge (carbonaceous rocks) in the immediate neighbourhood of the city, and again emerges into the plain partly occupied by the estuary of the Exe. The River Exe emerges from a narrow opening in the hills to the NW., and debouches into the plain of the Culm as if by mere accident.

Transverse Gorges in Chalk Hills.—Space will only allow a few of these being mentioned, though they constitute a very characteristic feature in the surface-geology of England. The River Stour, after traversing a great part of the plain of Blackmore (Dorsetshire), suddenly escapes through a narrow gorge in the chalk range of hills, near Okeford, and then finds its way in the direction of Blandford. It is evident that any theory which would account for the gorge by the degrading action of the river commencing at the level of the summit of the chalk range, must be rendered capable of explaining the transportation, through the same outlet, of all the matter by the removal of which the ground has been lowered to the level of the plain of Blackmore. In other words, the theory of the fluviatile erosion of transverse gorges, involves the formation of plains by atmospheric agency. The Wiltshire Avon, after flowing over low ground near Devizes, passes through a gorge in the chalk table-land, in its course towards Salisbury. In the Wealden area of Sussex and Kent, no less than nine rivers, after flowing through plains and valleys of gault, greensand, Weald clay, and Hastings sand, escape through gorges in the bounding chalk escarpments—the Arun, Adur, Ouse, and Cuckmere, through the South Down escarpment; the Wey, Mole, Darent, Medway, and Stour, through the North Down escarpment. Most of these rivers, for considerable distances, flow over flat plains before entering the chalk gorges. Some of them run only through valleys. (See *Escarpments of the Weald.*) To the west of the London Tertiary Basin, the Thames, after traversing a flat plain, passes through a gorge in the Chalk Downs, near Goring. In the chalk range to the NE. (including the Chiltern Hundreds), the rivers do not run through the escarpment, but away from it, so as to necessitate a reversal of the explanation applied by some subaërialists to the chalk escarpments of the Weald. (See *Origin of Longitudinal Valleys, &c.*) It can scarcely be said that the Trent, Ouse, and other rivers escape through the chalk range of Lincolnshire and Yorkshire, as the gorge of the Humber is still occupied by salt-water.

Longitudinal Valleys, Basins, and Transverse Gorges in Somersetshire and its Borders.—Between Bradford (Wilts) and Bath, the River Avon, after flowing through a plain in which it has excavated a true river-channel, in some places of considerable depth, finds its way in what at first appears a very inexplicable fashion through a very narrow and deep gorge, by which a hill has been completely divided. The rocks on the sides of this gorge show traces of the action of the sea, and the gorge, being a thoroughfare-pass, can be easily explained by the excavating power of currents. At Bath the river enters a wide basin. It again runs through a gorge, again through a basin, and so on to the Bristol Channel. The gorges and basins have been excavated in oolite, lias, new red sandstone, and coal-measures. Some of these alternate expansions and contractions must be included in Messrs. Phillips and Conybeare's enumeration of ten instances of transverse valleys between longitudinal valleys in the neighbourhood of Bristol. The expansion through which the 'lazy-flowing and mud-collecting Avon'* runs near Keynsham is quite flat-bottomed, and is surrounded by steep regular escarpments, the plain on the top of which is parallel to the plain below. No expansion of the rain theory

* Sir R. I. Murchison. *Address to the Geol. Section, British Association, Birmingham,* 1865.

will explain the flatness and regularity of the Keynsham basin. The gorge of the Avon at Clifton, which has been partly excavated in mountain limestone and partly in old red sandstone, has not yet been quite deserted by the sea.

Professor Jukes, in applying his subaërial theory to the explanation of this gorge,* supposes that the limestone which ought to have been degraded into a longitudinal valley was protected from subaërial dissolution by a capping of newer rocks, while the longitudinal valley behind was excavated. It is obvious that this method of accounting for the non-dissolution of the limestone will not apply to such localities as the Vale of Winscombe. As this vale contains dolomitic trias resting on mountain limestone and old red sandstone, it must have been scooped out of the latter formations before the triassic period. What, then, was there to protect the now surrounding limestone ridges from subaërial decay while the vale was in course of being denuded out of the nucleus of the Mendips? and while (according to Professor Jukes' theory) the gorge between Crook's Peak and Hutton Hill, through which the drainage now escapes, was in course of being worn down through the limestone? † There are many other localities where the limestone would appear to have been exposed to the atmosphere, while the longitudinal valley behind was in course of being excavated, according to Professor Jukes' theory.

Between Clevedon and Pill there is one of the most extraordinary longitudinal valleys in South Britain. It is bounded on the SSE. by the south-westerly extension of

* *Geol. Mag.* vol. iv.

† There is no indication of the coal-measures having ever covered the limestone range of the Mendips south of the Vale of Winscombe.

Leigh Down, and on the NW. by Weston Down, which separates it from the sea. On the north-west side of this valley there are picturesque indentations more or less cwm-shaped. It is quite open towards the NE., and shut up on the SW. by the hill which separates it from Clevedon. The narrow gorge leading out of it into the marshy plain east of Clevedon has been excavated in mountain limestone, and to a certain extent probably re-excavated in the trias which lines it. As the valley merges into similar marshy ground at its other end, near Portishead, and as both marshlands are admitted to be sea-bottoms of the *Scrobicularia*-mud period, if not of a more recent period, it is difficult to regard the narrow connecting gorge in any other light than that of a sea-strait, the time of the excavation or re-excavation of which is uncertain. The neighbouring form of the ground is inconsistent with the idea of a river here wearing down a gorge while a longitudinal valley was in course of being scooped out by rain.

Longitudinal Valleys and Transverse Gorges in South Herefordshire, Monmouthshire, and Breconshire.—Regarding Herefordshire as a great irregular old red sandstone longitudinal valley, and the narrow channel of the Wye, partly in Herefordshire and partly in Monmouthshire, as a limestone transverse gorge, the old red sandstone has been the rock on which rain has chiefly acted, and the mountain limestone the resisting rock. Professor Jukes has endeavoured to get over this difficulty by assuming that the old red sandstone of Herefordshire is so soft as to form an exception to the general rule as regards limestone being the yielding rock.* But the

* See his remark on one of my objections to the subaërial theory, in *Geol. Mag.* vol. iii.

narrow channel of the Wye has been excavated in old red sandstone as well as limestone, showing that no rule as regards easier atmospheric denudability can be established; and that the ocean which in *general* removes the rocks most amenable to mechanical action, but *often* likewise the hardest and most compact materials, is the only agent which can satisfactorily explain the complex phenomena under consideration. This will still further appear, if we regard the open area to the east of Brecon and west of the Black Mountain as a longitudinal valley, and the valley of the Usk between this area and Abergavenny as a transverse gorge. Both area and gorge have been excavated out of old red sandstone, which is covered at a high level on each side of the gorge by mountain limestone—on the S. by the outcropping limestone of the South Wales coal-field; on the N. by the solitary patch of Pen-cerreg-calch (2,260 feet above the sea). This well-known patch (already referred to) is a monument of denudation, perched high in the air, as if to bear witness to the extent to which elevated regions may once have been covered by deposits which have been swept clean away with the exception of a few forlorn wrecks. But the very nature and position of these wrecks renders it difficult to believe that a *vertically-operating*, or atmospheric cause, capable of denuding both old red sandstone and mountain limestone, should have left any portion of the latter while so much havoc was committed with the underlying strata.

Longitudinal Valleys and Transverse Gorges of North Herefordshire and South Shropshire.—This region (including a part of Worcestershire) abounds with these phenomena. The rocks in which they occur, and the internal structure of the valleys and gorges, have been minutely described by Sir R. I. Murchison, in his 'Siluria' and

'Silurian System.' Along the courses of the Lug and the Teme, they are very instructive in a theoretical point of view. The Lug, below Aymestry, flows through several valley-expansions and transverse gorges in ridges of the old red sandstone formation. On walking from Aymestry to Wigmore, the unbiassed observer is struck with the apparently accidental connection of rivers with the main valleys, for instead of finding the Lug all the way by his side, he sees it unexpectedly emerge from a lateral gorge on the left. By-and-bye, he finds himself in the open area or rather plain of Wigmore, a great part of which is still marshy, and a considerable part of which was once a lake. All the drainage of this area now escapes through the narrow Downton gorge (Downton and old red sandstone). The area itself has been denuded in some measure irrespectively of structure, though structure has given the general direction to the denudation. Any theory applicable to this area would require to be capable of accounting for the existence of a lake-basin—a phenomenon which no one would attempt to explain by rains and rivers; and as no glacier could here have had an adequate inclination of plane to give it an excavating power, this longitudinal valley would appear to have been scooped out by some sweeping form of marine action; for, as Sir R. I. Murchison has remarked, it has been disembarrassed of the detritus which a weaker kind of denuding action must have left. The River Teme, before finding its way into the Downton gorge, makes a series of awkward-looking bends, apparently indicating that its original SE. course was diverted into a NE. direction. On emerging from the gorge into Corvedale, and after flowing through a plain, the Teme joins the Corve, and their united waters run through a narrow gorge at Ludlow which has been excavated in Ludlow rock; but there is no reason for supposing this rock more resisting than the old red sandstone of Corvedale.* In the neighbourhood of Brimfield, the Teme flows over part of a plain covered with finely-stratified marine drift and shingle. Between Tenbury and the Vale of Worcester it traverses several valley-expansions and outlet-gorges in old red sandstone and other rocks, which form exceedingly picturesque scenery. (For notices of valleys and gorges along the course of the Severn, see *Excursions.*)

Longitudinal Valleys and Transverse Gorges near Llangollen.—The principal attraction of the scenery around Llangollen arises from the number of very deep valleys and gorges which are crowded within a small compass. The main part of the vale may be regarded as consisting of two parts which are separated by the rising ground connecting Castel Dinas Bran with the eminence on the opposite side of the river. The River Dee runs through a narrow gorge in this rising ground, and Mr. D. C. Davies, of Oswestry, believes that the gorge was worn down by the river, as it formerly emerged from a lake. If so, it must have been before the glacial submergence, as both above and below the gorge, the river now flows in a channel cut down through marine boulder drift, which rises in more or less regular terraces on each side. It is, however, possible, if not probable, that the present Vale of Llangollen was at one time entirely divided by elevated ground where the gorge now occurs, in which case the River Dee may have found an outlet through the pass of Pengwern. At that time the vale may have stretched from the head of Valle Crucis to Pengwern by way of Plas Newydd. On looking down from the top of the Eglwyseg cliffs, the original SSE. and NNW. contour of the vale, as above supposed, can

* According to the subaërial theory the siliceous sandstone would be more resisting than the argillaceous mudstone.

still, I think, be traced—the only breaks to its continuity being the gorge below Llangollen town, already noticed, and the gorge between Pentre felin and Llantysilio railway station. On following the Dee northwestwards, we are struck with the abrupt commencement of the last-mentioned gorge. From most points of view no trace of its existence can be seen. That the hills on the N. and S. were once continuous cannot be doubted. Beyond this fine specimen of a transverse gorge, we have not only the alluvial valley-expansion of the Dee, near Llantysilio,* but a flat-bottomed valley extending in a northerly direction, and opening into Valle Crucis. This, though at a higher level than the channel of the Dee, is the true longitudinal valley. It is not only quite open at its northern end, but crosses a watershed, and apparently the site of an old lake, where the ground is still marshy. This valley, then, could not have been *wasted out* by rain while the Dee was wearing down the transverse gorge at its southern end, unless rain can be supposed capable of excavating a flat-bottomed pass. Under a part (only a part), of the Eglwyseg escarpment (see *Limestone Escarpments*), there is a very remarkable longitudinal valley. It is connected by a deep transverse gorge with Valle Crucis. Northwards it extends as far the World's End (see *Excursions*); southwards it rises and crosses a watershed. The Eglwyseg escarpment forms its eastern boundary throughout, and extends far beyond it in a southeasterly direction. The transverse gorge opens out of a narrow part of the valley. The valley contains two

* As regards beautiful combinations of scenery, the near and distant prospects from Llantysilio are not perhaps surpassed in South Britain. They embrace wood, water, verdant and rocky slopes, and the finest variety of mountain shapes, culminating in the peak of Moel Morfydd, about three miles to the north-west.

longitudinal streams, flowing towards each other from nearly opposite points of the compass, two transverse small streams which run down from inlets or coves of the Eglwyseg escarpments, and several transverse runlets on its western side. It approaches the nearest to Professor Playfair's idea of a longitudinal valley of any I have seen, and the pluvial theory might be applied here, while elsewhere it might be consistently rejected; as this is not a longitudinal valley of the most usual form, but rather two tributary valleys meeting each other at nearly right angles, and finding their common outlet in a transverse valley. But even here there are difficulties in the way of the application of the fluvio-pluvial theory—such as the southerly graduation of the long valley into a pass under the Eglwyseg escarpment; the farther south-easterly extension of the pass between the escarpment and the circumdenudated cone of Castel Dinas Bran; the traces of sea-action on the face of the escarpments; the fact of the transverse gorge having been scooped out of the same rock with the ridge on its southern side (Wenlock shale), while the ridge on the north consists of Llandeilo strata; the fact of the valley being narrow where the gorge commences, while it expands southwards and northwards; the fact of both valley and gorge having been, in a great measure, excavated out of the same Wenlock and Llandeilo strata, &c.* It ought likewise to be considered that the area has been faulted to a great extent, and that the resulting fractures, or linear juxtaposition of hard and soft rocks, may have given a direction to, and facilitated the progress of marine denudation; for

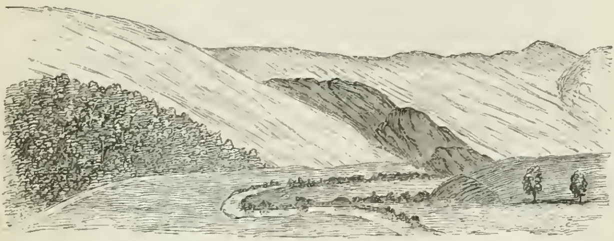
* The somewhat rubbly and incoherent representatives of the old red sandstone (and Ludlow rocks?) which crop out beneath the Eglwyseg limestone, may, by their easier denudability, have given the general direction to the longitudinal valley.

it is much easier to conceive of the sea *widening* a rent, and laterally stripping off a broad mass of soft strata bounded by a fault, than it is to conceive of fresh-water streams producing the same effects.

Cross-Denudation near Llangollen.—On looking down from the neighbouring heights into the deep valleys comprising or ramifying out of the great Vale of Llangollen, one can recognize two sets of valleys—long valleys running approximately parallel from N. and NW. to S. and SE., and short valleys from W. to E.; but whether one set was superimposed on another set, or both sets formed at the same time, it would be difficult to determine.

Longitudinal Valleys and Transverse Gorges in Central Wales.—On travelling along the upper course of the Wye, beyond Three Cocks Railway Junction, we enter a long narrow gorge, and emerge near Builth into an irregular open area. The gorge has been excavated in Ludlow rocks; the open area in a variety of rocks, consisting of Wenlock and Llandeilo beds, erupted trap, &c. On arriving at Newbridge Station, a good-sized level plain, covered by marine drift, may be seen stretching N. and S. In this plain the actual channel of the River Ithon is sharply defined, and is as distinct from the plain itself as any two phenomena can be. The course of the Wye then passes through a series of gorges, small valley-expansions, and longitudinal valleys until it opens into the wide Vale of Rhaydr. This vale furnishes about as good a specimen of a longitudinal valley as any in Wales. Excepting where it graduates into the valley of the Elan, and into Gwyn Llyn Cwm (see *Silurian Escarpments*), its outline is regular and in most places smooth. The Wye enters it from the NW. through a gorge, the sides of which commence from above so abruptly that excepting from a few points of view its existence would not be suspected. After bending round in the usual fashion, and flowing longitudinally for some distance, it escapes through the gorge which commences very suddenly on the side of the ridge bounding the vale on the SE. (See

Fig. 58.



Transverse Gorge south of Rhayadr.

Fig. 58.) The vale and this gorge have been excavated in the same Lower Llandovery formation, though the

Fig. 59.

Bird's-eye View of Gorge and Basin north-west of Rhayadr.

ridge on each side of the gorge consists in many places of hard sandstone and conglomerate. Fig. 59 represents the gorge through which the Wye enters the Vale of Rhayadr. It communicates with a deep basin surrounded by very precipitous slopes which, on the side most distant from the river-channel, present one of the finest and loftiest rocky cliffs in the principality. On the northern side of this basin the Wye and the Marteg meet. Whatever share the Wye may have had in excavating the basin down to a certain depth, it is obvious that the basin itself (a considerable part of the bottom of which is boggy and looks like an extinct lake) has been scooped out by a great body of water, if not of ice, capable of exerting a gyratory action. There is nothing in the composition or structure of the rocks forming the area of the basin which would have rendered them more amenable to pluvial or fluvial action than the rocks of the surrounding table-land. Appearances justify the conclusion that the small stream which enters the basin from the west by a series of cascades, traversed its now upland valley before the basin was excavated. The valley of the Wye, considered as distinct from the basin, then probably likewise existed, and the agency which whirled out the basin may have had its course directed and its reflex or gyratory motion determined by the confluence of the two valleys. In the neighbourhood of Aberystwyth the River Rheidol passes obliquely through several transverse gorges in ridges separating longitudinal valleys. The scenery in the valley of the celebrated lead-works, Goginon, is likewise very instructive.

Numerous additional instances of basins, valley-expansions, longitudinal valleys, and transverse gorges in Wales, and likewise instances in North Staffordshire, Derbyshire (especially near Matlock—see *Limestone Escarpments, &c.*), Yorkshire, and Lancashire might be noticed, did space permit; but I must conclude this chapter with some account of the

Longitudinal Valleys and Transverse Gorges of the Lake District.—The Lake District is far from being remarkable for the association of longitudinal valleys with transverse gorges. The longitudinal valleys are often occupied by lakes which have an outlet in a longitudinal direction. There are gorges in the barriers of some of the lakes, as in the case of Elter Water, Crummock Water, and several others. Grasmere Valley approaches nearer to the character of a longitudinal valley than perhaps any other in the district. The gorge between Nabb Scar on the N. and Loughrigg Fell on the S. is a good instance of a transverse gorge. It commences so abruptly that a distant or even a near view from most points, would scarcely lead one to suspect its existence. The occurrence of a lake (Rydal Water) in this gorge is a very important fact, showing that it could not have been excavated by a river. There are many valleys in the Lake District, some of them reaching the dimensions of vales, without any lateral breaches or outlets, which may still be called longitudinal. They are distinct from passes declining at both ends, and more or less distinct from valleys, which rise gradually towards their inner ends, and thin out or narrow off towards watersheds. Nearly all the valleys containing lakes come under this character, as well as a number, such as Great Langdale, which contain level expanses of alluvium or drift. All those valleys which are more or less trough-shaped; the lower ends of which are as confined (outlet-gorges excepted) as their upper; the bottoms of which are flat or hollowed out so as to hold lakes, marshes, bogs, or deep deposits of drift or alluvium, may, for the sake of distinction, be called longitudinal valleys. They present no real indication of having been formed by rivers, while it is certain that their excavation, if not entirely effected, must have been completed by an agent capable of acting without an inclination of plane.

Borrowdale and Watendlath.—The upper part of Borrowdale may be regarded as a valley-expansion or longitudinal valley with two outlet-gorges. A considerable part of the valley is an alluvial or drift flat, and excepting for the gorge between the Bowder Stone and Castle Crag, it would be a lake-basin. But, leaving drainage out of consideration, it may be said to have two outlet gorges, one on each side of Castle Crag, a

Fig. 60.

The Gorge of Borrowdale between the Bowder Stone and Castle Crag (looking South).

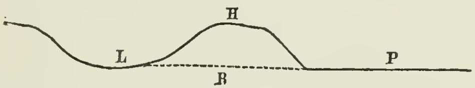
rocky eminence which reminds one forcibly of an island dividing two narrow straits.* Fig. 60 will give an idea of the northern outlet of Borrowdale, through which the Derwent flows. But we have no reason for supposing that this pass and the pass on the right of Castle Crag were excavated by different agencies, though the pass now occupied by the river may have been deepened by its action. The existence of two passes or gorges so near to each other, while one would have been sufficient

* The entrances to Borrowdale from the Keswick end are sometimes unwittingly called the Straits of Borrowdale.

for the drainage of Borrowdale, would appear to favour the idea that neither of the gorges were made by the drainage, and that the drainage merely took advantage of one of them. At a height of about 500 feet above the level of Borrowdale is the celebrated upland basin and gorge called Watendlath Valley. Watendlath Tarn is 847 feet above the sea. The western side of the basin containing this tarn communicates with Borrowdale by a shallow pass. The gorge between the basin and the waterslide, called Lowdore, is narrow, and the rocks, especially on the eastern side, appear very cleanly swept.

Theories relative to the Origin of Longitudinal Valleys and Transverse Gorges.—A number of theories attempting to account for the excavation of longitudinal hollows and the narrow gorges, with high ground on each side, which form their outlets, have been given to the world.

Fig. 61.



Section of Longitudinal Valley and Transverse Gorge.
L Longitudinal Valley. H Hill. P Plain. R River.

It is obvious that the explanation must be chiefly directed to the fact of a river, in the lower part of its course, flowing through a breach in ground higher than that forming the upper part of its course—in other words, to the phenomenon, as it would appear from most points of view, of *a river running through a hill* (see Fig. 61, in which the dotted line represents the river-channel); but the explanation, to be satisfactory, must include the longitudinal valley, valley-expansion, basin, or plain which the river traverses before it runs through the hill.

Theory of Colonel Greenwood, Professor Jukes, Mr. Whitaker, and others.—These geologists, in their explanation, consistently include escarpments and the plains stretching along or away from the bases of the escarpments. The escarpments they treat as hills and ridges, and the plains as wide longitudinal valleys. Their theory is a modification of Professor Playfair's idea,* already noticed. Colonel Greenwood† states it as follows :—'A stream running through ridges, large or small, is the simple consequence of the differing hardness of the ground through which it runs. In all cases a stream cuts for itself a narrow channel, the depth of which is determined by its hardest part. . . . But the wash of rain digs down where the ground is soft, and leaves hills or ridges where it is hard. And as a stream cuts through a hard stratum, say the North or South Downs, the wash of rain is scooping out two lateral valleys *behind* it—that is, a valley behind each side of the gorge and ridge, as in the Weald clay. . . . The débris of these valleys is carried off by the lowering bed of the river. A ridge is then developed, and the river runs through a gorge in the ridge. . . . Directly as the softness is the width. Above each hard gorge will invariably be a comparatively wide horizontal valley. . . . . Rivers have the power to cut narrow channels or *ravines*, but they have very little power of widening these. Disintegration and the wash of rain widen these ravines into broad valleys. While this is going on, rivers convey to the sea what rain brings to them ; . . . . rain is constantly shoving the whole surface of the earth down towards the sea.' Professor Jukes has perhaps stated his development of the subaërial theory more clearly in the 'Geological Magazine' (vol. iii.

* See *Introduction*, p. 5.

† *Rain and Rivers*, and *Geol. Mag.* Sept. 1867.

p. 233)* than in any other part of his writings:—'The reason why the rivers choose to run through the hills by deep ravines, instead of by much easier routes [?] which are now open to them, is, that when they began to run, these hills did not exist. The hills were then buried, as it were, in much higher ground, by which they were surrounded, and over which the rivers originally ran. The rivers choosing of course the lowest ground they could find in their course to the sea, happened here and there to cross the parts where these hills subsequently became disclosed by the waste and erosion of the rock which surrounded them. The rivers, however, having once cut channels for themselves, have ever since kept these channels open, and it is through these channels that the waste of the interior has been carried off. Although then the interior was worn down into a plain, while the hill-ground resisted that action and was left standing as a hill, the river-channel through that hill was always cut lower than any part of the plain, for it was only in consequence of the deepening of that channel that the waste could be carried off, and the erosion of the surface of the plain continued.

'In Ireland the rock that was thus wasted in the interior was carboniferous limestone; the ground that stood as a hill was old red sandstone, or some other siliceous rock.

'The calcareous rock was acted on both by mechanical erosion and chemical solution, the siliceous rock only by mechanical erosion. The siliceous rock therefore resisted the atmospheric action far more than the calcareous rock did: but it would not have thus resisted the sea, which would have cut into the old red sandstone just as easily as into carboniferous limestone.'

* In a letter opposing my views of denudation published in previous numbers.

Dr. Foster and Mr. Topley, as already remarked, have systematised and applied the above theory to the denudation of the Weald. (See *Chalk Escarpments, &c.*) Mr. Whitaker, F.G.S., has very lately been writing on the denudation of the chalk districts ('Geol. Mag.' vol. iv. Oct. and Nov. 1857). I have just learned from this accomplished geologist (March 1868) that he regards the low ground at the base of an escarpment as a 'longitudinal valley,' when opposite to the escarpment the lower beds also rise up into higher ground within a few miles, as is often the case along the chalk scarp of Surrey. North of London, however, the ground is either transversely level, or falls gently away from the chalk escarpments, for many miles, as in the Vale of Aylesbury. Mr. Whitaker has also directed my attention to his having in 1864 ('Geol. Survey Memoir,' on Sheet vii. p. 98) proposed a modification of the subaërial theory in its application to the chalk districts, of which the following is the substance :—N. and NW. of London, the river-valleys do not cut right through the chalk scarp, and the rivers therefore do not flow through it. On the SW., S., and SE. of London, *where the dip is sharper*, the river-valleys do cut right through the chalk scarp. Is it possible that in the more northerly of these districts we see a state of things that existed ages ago in the more southerly? and may not the valleys in the north be gradually worn back, and deeper, towards the scarp, so that the rising point of their streams may gradually get nearer and nearer to that scarp? And if this go on for ages, will not these valleys at last work their way back and quite through the chalk ridge, so that the water that now flows away from these hills (over the beds below the chalk), and in a roundabout way to the Thames, will join the water of the chalk streams in their far more direct flow into the same river, and the north district will then be as the south one is now? *

Objections to the Subaërial Theory in its application to Longitudinal Valleys, Transverse Gorges, Plains, &c.—In addition to what I have already said concerning the untenableness of the subaërial theory in different parts of this work, it may here be sufficient to state very briefly the following objections:—(1.) It does not explain the independent contour of the longitudinal valleys—that is, the contour they possess irrespectively of the transverse gorges. (2.) It does not explain the smoothness, uniformity, and curvilinear regularity of many longitudinal valleys and valley-expansions. (3.) It offers no explanation of the important fact that many of the transverse gorges leading out of, or into longitudinal valleys have a *fresh aspect* and commence abruptly. The brinks of their precipitous sides are generally sharply defined, and they open suddenly and unexpectedly on the sides of the longitudinal valleys, instead of the longitudinal valleys graduating into them, in trumpet-mouth-shaped fashion, as would be the case had rains and rivers simultaneously excavated both. According to the subaërial theory the brinks of the precipitous sides of the gorges were the first formed, and ought (notwithstanding the comparative hardness of the rocks) to have become bevelled and rounded off during the subsequent eternity that was consumed in dissolving away the longitudinal valley. (4.) It does not explain the depth of excavation required to admit of the formation of peat, swamps, and thick beds of alluvium in longitudinal valleys; in other words, all subaërial erosion and transportation must have ceased before many longitudinal valleys were reduced to the degree of longitudinal flatness they now

* This theory will be considered under the head *Origin of Passes.*

possess. (5.) It does not explain the origin of the wide and flat-bottomed vales and plains which often occupy, in relation to transverse gorges, the place of longitudinal valleys. (6.) It does not satisfactorily account for the *dry* passes which often connect valley-expansions, and which according to the theory ought to be river-gorges, or ought to have been river-gorges, but which contain no traces of river-action. It takes for granted a correspondence between the pluvial (including chemical and fluvial) denudability of rocks which does not exist, and involves contradictions, or assumes improbabilities, in making limestone, for instance, the most yielding rock in one district and the least yielding in another; and when it offers some explanation on this point, it still attributes a relative amount of denudability to different rocks which is inconsistent with facts.* (7.) The history of its practical application shows that it requires the assistance of a sliding-scale to an unwarrantable extent, and an inadmissible amount of modification, before it can be made to suit different localities.

Sir John F. W. Herschel on Transverse Gorges.—This eminent authority on almost every subject, in his 'Physical Geography,' says: 'When a river . . . which has run for some distance between parallel mountain-chains, escapes by a cross-valley laterally, such valley is very commonly identifiable by the inclination of the strata on either side of it as a valley of cross-fracture,

* The reason assigned why limestone is the most yielding rock, is its amenability to chemical solution as well as mechanical erosion, while sandstone is only affected by mechanical erosion. But where the transverse gorges are in limestone ridges, the theory is made to shift its ground, and attribute a degree of susceptibility to mechanical erosion in the sandstone, because it is soft, which far exceeds the combined chemical and mechanical denudation of the limestone; but in so doing, it obviously over-estimates the power of rain and small streamlets to act mechanically on even soft rocks.

accompanied with its own peculiar dislocations. And in some cases earthquakes have been known to open channels by which the courses of rivers have been diverted.' That cross-fractures may, in many instances, have guided the excavating agents, and that sea-currents as well as rivers may have had a direction given to their erosive action by such fractures, cannot be doubted. In some gorges (as already noticed) the denudation may have been equal to the removal of all traces of the guiding or directing fracture; in others the signs of the internal disturbance of the strata might remain: but it becomes a question how far a fracture arising from an anticlinal upthrow or a fault could leave a ready-made transverse valley, or do anything farther than 'initiate,' its formation by denudation. Sir R. I. Murchison tells us that the lateral or outlet gorge of the Woolhope basin, or 'valley of elevation' (which may be regarded as two 'circumfluent' longitudinal valleys), occupies the site of a great transverse fracture, but his reference to it implies that it must have been at least cleared out and enlarged by a sweeping denudation. (See *Denudation of Valleys encircling Central Domes.*)

Professor Ramsay on Transverse Gorges.—This great denudational authority admits that the gorge of the Chalk Downs traversed by the Thames between Goring and Reading, and the gorge occupied by the Humber, both owe their existence to the chalk rocks having been breached through by the sea.* To leave the reader to suppose, however, that Professor Ramsay would account for all transverse gorges in the same way, might be to convey an erroneous impression; for I have reason to believe that, like a true philosopher, he would vary his

* *Physical Geology and Geography of Great Britain.*

explanation to suit diversities of internal structure and surface-configuration.

Sir R. I. Murchison on Transverse Gorges.—Sir R. I. Murchison believes that, as the land was successively upheaved, lakes must have been left in hollows; that the transverse or outlet gorges must have been deepened by the sea running through them, so as to let off large volumes of water; and that in course of time estuaries must have been desiccated, and strings of lakes reduced to rivers.* There can be no doubt that during the rise of the land, gorges must have been deepened and widened, if not entirely formed, by the action of the sea—either alone, or co-operating with fresh water; and it is highly probable that since then the excavating power of rivers has deepened the outlets of many longitudinal valleys, so as to drain the lakes they previously contained down to the level of the alluvium, marl, or peat by which the sites of these lakes are now marked.

Sir Charles Lyell's Theory.—The following passage in Lyell's 'Elements' must be regarded as including longitudinal valleys, if not transverse gorges: 'The action of waves and currents on land slowly emerging from the deep affords the only power by which we can conceive so many deep valleys and wide spaces to have been denuded as those which are unquestionably the effect of running water.'

Mr. Darwin believed † that transverse gorges, as well as longitudinal valleys, were formed by the sea, during a gradual rise of the land, as quoted in the *Introduction* to this work.

I can see no explanation so little beset with difficulties as that which would mainly refer the scooping out of

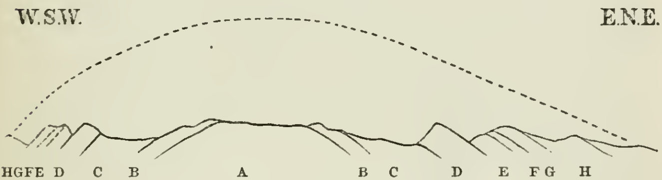
* *Silurian System.*

† I have no reason to suppose that Mr. Darwin has changed his views on this particular point.

longitudinal valleys, valley-expansions, and basins to the action of oceanic currents at 'moderate depths,' assisted at intervals by great rushes of water produced by the sudden elevation or depression of submarine areas. With regard to transverse gorges, I think that most of them present indications of their having been excavated subsequently to the formation of the longitudinal valleys, by oceanic currents and waves, directed by fractures, faults, or previously-existing shallow passes, during a gradual emergence, or a series of gradual and sudden emergences of the land.

Denudation of Valleys encircling Central Domes.—The most remarkable instance of this very interesting phenomenon occurs in the SE. of Herefordshire. Fig. 62 is a rough outline sketch from the elaborate

Fig. 62.



Section of Woolhope Valley.

A Upper Llandovery Rock. B Woolhope Limestone. C Wenlock Shale. D Wenlock Limestone. E Lower Ludlow. F Aymestry Limestone. G Upper Ludlow. H Old Red Sandstone.

section in Sir R. I. Murchison's 'Siluria.' The dotted line represents the extent of the denudation. Sir Roderick says: 'One of the most striking features for the consideration of the geologist is, that neither the central dome nor surrounding ridges, including the outer encircling ring of Ludlow rocks, offer a trace of drifted matter or gravel, or even any remnants of the various strata which must, in the process of elevation, have been at first bent over in the form represented by the dotted lines, and afterwards demolished. All the débris resulting from the destruction of this once great solid mass has therefore been swept out, the tract being one of clean denudation' (p. 110, 4th edition). 'What agency, I ask, except that of very powerful currents of water, could have removed every fragment of the débris that must have resulted, whether at one or several periods of elevation, from the destruction of all the once superposed arches of rocks, and have scooped out all the detritus arising from such destruction, from the circling depressions, the central dome, flanking ridges, and former cover of these Silurian strata? And if that water had not been impelled with great force, caused by sudden uprises of these rocks from beneath the old red sandstone, what other agency will account for so complete a denudation, the broken materials having only found issue by one lateral gorge? . . . Whether we embrace the hypothesis of a sudden expansion or of a number of shocks, we are compelled to call into play the action of currents, both violent and long continued, to explain satisfactorily the great extent of erosion' (pp. 492, 493 'Siluria,' 4th edition).

CHAPTER XIV.

ORIGIN OF VALLEYS—*continued.*

PASSES AND V-SHAPED SLOPING VALLEYS.

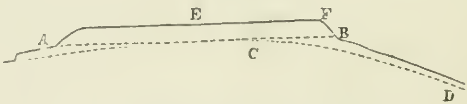
Some longitudinal valleys, as already hinted, may be regarded in the light of passes deeper in the middle than at each end; some long passes contain longitudinal valleys; and all transverse gorges running between longitudinal valleys and plains may be looked upon as passes higher at one end than the other.* But the word *pass* is usually limited to a valley-thoroughfare lower at each end than in the middle. It ought, however, to include those long and generally continuous valley-thoroughfares which cross several lines of watersheds, as well as those which cross only one line. Among the more remarkable and instructive passes of England and Wales, the following may be noticed. They include nearly all degrees of longitudinal inclination, from the almost perfectly flat-bottomed pass to the form approaching that of the Alpine col.

Passes of Devon and Somerset.—In the neighbourhood of Torquay the geological tourist may find a number of passes on a small scale, but still very instructive: between King's Kerswell and the Torquay Railway Station, near the culminating level of which Torre Station is situated (Triassic or Permian (?) sandstone and Devonian limestone); between Ansty's Cove and Kent's Cavern; between Torquay and Meadfoot Crescent (Devonian limestone); Stonycombe, on the line of railway, about half way between Newton Bushell and Totnes (Devonian limestone and slate), &c. In North Devon and West Somerset the great Exmoor table-land is traversed by shallow passes deepened at one or both ends into sloping stream-valleys. On the sides of this table-land the upper ends of V-shaped stream-valleys are often connected by passes. Between the eastern part of Exmoor

* The so-called Pass of Aberglaslyn, near Beddgelert, is perhaps the finest gorge (with a valley-expansion above and below) in Wales. Its bottom, in many places, is so narrow as to leave only room for the stream, the road being indented on the steep slope. The cliffs on both sides are very steep, and at the summit the distance between them is so small, that instances (it is said) have occurred of shepherds quarrelling with each other across the gorge, while they were a day's journey apart by any accessible road. If so, before coming into personal collision, they would have had time to cool down!

(Brendon Hill) and the Quantock range of hills there is a pass on a large scale, which must have been excavated in Palæozoic times in Devonian slate, as it is lined with Permian and Triassic sandstone, breccia, and conglomerate. These infilling strata, especially at the culminating level of the pass, have been denuded into inverted cup-shaped hills, with intervening passes, dry and wet. The railway from Taunton to Watchet runs through some of these passes. Several shallow passes, approaching the character of cols, divide the summits of the Quantocks (Devonian slate and limestone). The Black Down table-lands (as already observed) are separated by shallow passes which, in many places, graduate into stream and river valleys which have been dug down as far as the Trias. Fig. 63 is a longitudinal section of

Fig. 63.



Longitudinal Section of a Pass.

the pass above Blagdon: A Valley of the River Culm; AB bottom of pass; CD bottom of stream which flows into the Vale of Taunton; E table-land; F north escarpment.

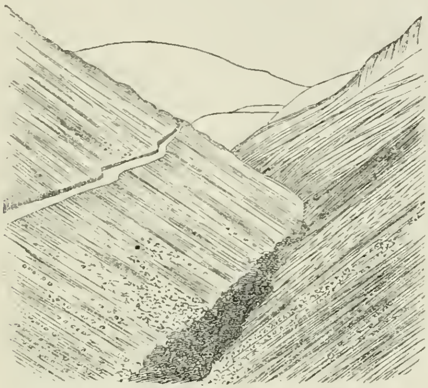
Between Glastonbury and Wincanton many narrow and deep passes may be seen on travelling by railway. On each side of the anticlinal axis of the Mendips, there are many passes which occupy the place of transverse river gorges, though they stand high and dry. The pass called Shuteshelve, between Sidcot and Axbridge, is bounded on both sides by slopes of great height; but the Longbottom Pass (already mentioned), between

Shipham and Cheddar, is more remarkable; it is indeed one of the most perfect and instructive specimens to be met with in England or Wales. Its sides are lofty and generally steep, and in one place consist of a line of limestone cliffs. Its culminating level is not only flat for a considerable distance, but much wider than the two ends. On the south-west side this culminating central area enlarges into a semicircular recess. Towards Cheddar the narrow southern end of the pass has been rutted by a tiny streamlet. At the north end there is likewise a very small streamlet, but neither of these streamlets take their rise in or near to the culminating flat part of the pass. We have no reason for supposing that they were ever much larger than at present. As they are indebted for the small watershed they possess to the pass, it is probable that previously to its excavation they had no existence. But allowing their former existence, they must have had hard work (according to the subaërial theory) to wear back their channels till their sources coalesced, and still harder work to have exerted a *maximum* force, so as to scoop out the great central hollow (see *sequel*), where their action had reached its *minimum*; or suppose, according to a modification of the subaërial theory, that one of the streams, say the southern, wore its channel backward through the table-land, until it could no longer resist the law of gravitation, and divided into two streams, the offspring running in an opposite direction, or towards the north, they must have had equally hard work in rendering the central the largest part of the pass. The sides and bottom of Longbottom Pass throughout consist of mountain-limestone resting on limestone shale.

Passes of South Wales.—Among these may be mentioned the pass in the South Welsh coal-field, which runs transversely to the Afon, Ebbw, Sirhowy, Rhymney, and Taff valleys. This long pass (supposed to run roughly along an anticlinal disturbance) commences at Pontypool, and is continued in the direction of Crumlin, Newbridge, Blackwood, and Quaker's Yard. It consists of four minor passes connecting the above valleys. The Ebbw river has apparently taken advantage of a southerly bend of this long pass, between Crumlin and Newbridge, in a manner which throws suspicion on any claim it may seem to possess as the sole excavator of the north and south valley through which it flows. There are many other fine specimens of passes in South Wales which for want of space must be left unnoticed.

Passes of North Wales—Tal-y-llyn.—This pass is about fifteen miles in length. It runs from the neighbourhood of Towyn on the SW. to the River Mawddach, near Dolgelley, on the NE. Its direction shows an unmistakable coincidence with certain great SW. and NE. features of the district, including the Valley of the Dovey on the SE., the Valley of Dysynni on the NW., and the intervening ranges of hills. The greater part of it is remarkably straight and continuous, and its sides are in general lofty, and in many places steep and precipitous. It has been excavated in Lower Silurian shales, slates, and felspathic traps or porphyries. Between Towyn and Abergwynolwyn it crosses a watershed, and at the latter place acts the part of a longitudinal valley. It is here crossed by a stream coming down from the SE., which joins the stream flowing from Tal-y-llyn, and then runs through a transverse gorge on its north-west side. The manner in which the two streams meet, and the extent to which the pass and transverse valley intersect each other, would seem to show that *both* streams have only an accidental connection with the pass. Beyond Abergwynolwyn the pass gradually rises towards Tal-y-llyn (see Fig. 64). Here the north-west side of the pass is formed

Fig. 64.



Part of Tal-y-llyn Pass, looking NE. or towards the Lake.

by the south-east rocky escarpment of Cader Idris, which in some places, is more than 1,000 feet in height. About three miles beyond Tal-y-llyn, where the pass reaches its culminating level of 859 feet above the sea, there is a small lake. The pass of Tal-y-llyn, in some respects, resembles the Great Glen in Scotland, which Professor Playfair believed must have been excavated by oceanic currents. There are numerous small passes in the Cader Idris district, and a number of very striking gaps in the Cambrian district to the north of the River Mawddach.

Bwlch-drws-ar-dudwy.—'In the pass of Bwlch-drws-ar-dudwy the rocks are singularly bare of vegetation, and for a height of about a thousand feet from the base to the very summit of the hills, the beds piled on each other, may be seen dipping steadily west, with gentle undulations, at angles varying from 25° to 30°, presenting one of the grandest spectacles, both geologically and as a piece of rugged scenery, that North Wales affords. Rhinog-fawr forms one side of the pass.'* I have not seen this pass.

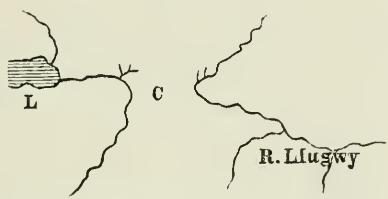
Pass of Llanberis.—The two passes of Llanberis and Llyn Ogwen cut right through the Snowdonian range of hills from SE. to NW. Llanberis is the best known. It has been excavated in Cambrian slate and grit, Lingula and Llandeilo flags, grits, and slates, and felspathic porphyry, lava, and ashes, with interbedded aqueous rocks of Bala age. It is approximately straight throughout its whole extent, including the lake-basins of Llyn Padarn and Llyn Peris. At its south-east end, a little beyond its culminating level, it merges into two valleys, Nant Gwynant and Nant-y-Gwryd, which form a long pass at nearly right angles to it, leading to Capel Curig on the NE., and to Beddgelert on the SW. The irregular area in which the three valleys meet (Llanberis, Nant Gwynant, and Nant-y-Gwryd), could not have been formed by the mutually retrogressive action of streams. It is only necessary to ascend the escarpment behind Pen-y-Pass Inn to see the untenableness of such a supposition. The Nant-y-Gwryd stream rises in a lake situated in a cwm on the side of Glyder Fawr, at a considerable elevation above the culminating level of the pass of Llanberis, and separated from it by a continuous rocky ridge. On reaching Pont-y-Gwryd, it bends suddenly towards the east, and then runs in a direction forming a high angle with that of the pass of Llanberis. The principal source of the Nant Gwynant

* Ramsay's *Survey Memoir on the Geology of North Wales*, p. 18.

stream, which flows at nearly right angles to the pass of Llanberis, is Llyn Llydaw, on the eastern face of Snowdon. The stream in Llanberis Pass is principally fed by runlets which flow down the sides of the pass, and not by the summit level watershed. In short, the principal sources of the streams flowing through the above valleys *ignore* each other to such an extent as to forbid the idea of these streams having excavated the passes into which the valleys graduate.

Pass of Llyn Ogwen.—The culminating level of Llyn Ogwen Pass is a little above the lake, and here we have a very instructive configuration of watershed area. As if the stream which flows towards Capel Curig and the stream which runs into Llyn Ogwen disclaimed having

Fig. 65.



The Sources of Streams ignoring each other in Llyn Ogwen Pass.
C Culminating Level. L Llyn Ogwen.

had any share in the excavation of the pass, the first originates in a cwm, containing Ffynnon Llugwy, under Carnedd Llewelyn, runs down a declivity into the pass, turns suddenly round at an angle of about 45°, and then flows along the pass in the direction of Capel Curig. The second stream runs down from Cwm Tryfan, enters the pass at right angles, and then turns round in the direction of Llyn Ogwen. The map, Fig. 65 (from the Ordnance Survey Sheet lxxviii.), will render this clear.

Among the other passes of the Snowdonian district

Fig. 66.

Passes crossing the Moel-Fammau Range of Hills, as seen from Rhyl Station.

the following may be noticed:—the long pass between Carnarvon and Beddgelert, the culminating level of which is near the well-known rocky projection called Pitt's Head; the pass between Y Ro, in the Vale of Conway, and Llanfairfechan, the highest part of which is Bwlch-y-ddenfaen. Near the north-east termination of the Snowdonian range, the two following low-level passes may be mentioned—between Conway estuary and Rhos Bay, and between the Great Orme's Head and the hills to the south of Llandudno, which extend from the Little Orme's Head to Conway estuary. These passes have perfectly flat bottoms.

Between Llangollen and the estuary of the Dee there is a great number of passes. The range of hills (chiefly Wenlock shale) including Moel Fammau, crowned by King George III.'s monument, is divided into short, isolated ridges, or conical eminences, by a series of elevated passes, which few, I think, would hesitate to regard as ancient breaches made by the sea. Fig. 66 represents the outline of this truly picturesque range of hills, and includes a distance of at least ten miles, from the limestone hills near Dyserth to beyond the neighbourhood of Ruthin.

Passes of Shropshire.—Among these may be noticed the narrow gorge which cuts through the Wrekin (see *Excursions*); the pass between the Long Mountain and the Shelve and Stiper Stones group of hills, which has a very flat floor of Wenlock shale, widens at both ends into a plain, and rises so gently to its culminating level that it is difficult to say where the latter occurs (Martinpool is situated in the middle area of this pass); Church Stretton Pass, which runs between the Cambrian Longmynd Mountain on the west, and the igneous Caradoc range on the east, and the middle area of which is so flat as to have been at one time a marsh if not a lake.* (See *Excursions.*) In North Staffordshire, Derbyshire, Yorkshire, and Lancashire there is no want of passes, but remaining space will only admit of our noticing those of the Lake District.

Passes of the Lake District.—Passes, in one shape or another, may perhaps be said to form the main feature of the Lake District of the NW. of England. There are comparatively few valleys which are not connected at their upper ends by passes. River-valleys, strictly so called, are exceptional in the Lake District; the reason being that the ground is so broken up as to leave little room for the existence of elevated areas or slopes of sufficient breadth to furnish watersheds for many powerful streams. In this district the passes graduate

* The frequent occurrence of marshy, peaty, or wet ground in the middle area, or between what ought to be strictly called the two culminating levels of a pass, has never been satisfactorily explained. To call in glaciers in every instance would, I think, be obviously going too far. The fact that the increased velocity of oceanic currents in the narrow parts of a pass would be likely to deepen its bottom, so as to leave a shallow basin, has, I believe, never been taken into consideration.

from deep valley-thoroughfares to mountain-cols. I have only space to notice a few of them.

Among the elevated long passes may be mentioned Wrynose, the culminating level of which is 1,270 feet above the sea; Styhead, the tarn in which is 1,430 feet above the sea; Gatesgarth, about 1,100 feet above the sea; Whinlatter, Grisedale, and Kirkstone passes. The last four deserve to be more particularly noticed.

Gatesgarth Pass.—This is perhaps the finest pass in the Lake District, especially as regards wild and rugged scenery. It is very narrow, and its sides very precipitous. At the culminating level or Hause, a stream enters the pass, at nearly right angles, from the south side, and runs towards Buttermere. Between the Hause and Buttermere, Honister Crag (Llandeilo slate), perhaps the highest precipice in the Lake District, rises up on the left hand to the height of 1,500 feet above the stream at the bottom of the valley.

Whinlatter Pass.—Though less rugged than most of the other passes of the Lake District, this is perhaps as much calculated as any to awaken ideas of solitary sublimity. In the central part, for a considerable distance, you feel yourself completely separated from everything connected with the world of mankind. Not very far from its culminating level, a stream from a cwm under Grisedale Pike, after it has acquired considerable volume, enters the pass, in the usual independent fashion, makes a sudden bend, and flows towards Bassenthwaite Lake; and although to the west of the culminating level, a small tributary stream takes its rise in, and runs along the bottom of the pass, the main stream which waters the north-western part of the pass flows into it from a fine cwm (already mentioned) on the south side.

Grisedale Pass.—This long pass may be said to extend from Ulleswater to Grasmere, so that the two brooks which traverse it in opposite directions have had space to excavate considerable channels. Near its culminating level, and under the eastern declivity of Seat Sandal, there is one of the highest sheets of water in the Lake District (1,768 feet above the sea) called Grisedale Tarn. From this tarn a pass runs in the direction of Dunmail Raise, which divides Seat Sandal from Helvellyn. Its culminating level is a peat bog. In the main or Grisedale Pass, the two streams, one issuing from the tarn, the other from the side of Fairfield, have no connection with the culminating area, which is depressed about 1,000 feet below the immediately adjacent heights. Grisedale Pass, according to Professor Harkness, runs along an anticlinal axis.*

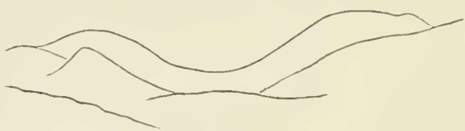
Kirkstone Pass.—On ascending from Ambleside towards this pass, one can scarcely fail to see that the brook, called Stockgill, has made a channel for itself in the previously-existing valley between the southern part of Kirkstone Fell and Wansfell. Before arriving at the pass (strictly so called), we see a wide lateral gap leading eastwards into Troutbeck Valley. Immediately before reaching the culminating level of the pass, the road crosses Stockgill brook, which issues sidewise from a recess in the rocky side of the highest part of Kirkstone Fell. The cliffs here are very rugged, lofty, and imposing, and are subject to the tumbling down of blocks and fragments, or screes, which point to an original *cliff-forming power* distinct from the present *cliff-destroying* action. The culminating area of this pass, about 1,300 feet above the sea, is enlivened by an inhabited house, one of the highest in England. Though at a considerable altitude, it is deeply depressed beneath the

* *Quart. Journ. Geol. Soc.* Dec. 17, 1862, p. 128.

summit of Kirkstone Fell, which is 2,541 feet above the sea. Among the large blocks which have fallen from Kirkstone Fell (some of them probably while the pass was occupied by the sea), the Kirk Stone, a nameless kind of lavaceous-looking trap, must not be left unnoticed. Beyond it, the pass becomes a narrow scree-strewn ravine, which leads down to Brothers Water.

Pass of Dunmail Raise.—This is perhaps the best specimen of a low-level pass in the Lake District, and it was perhaps better known than any other previously to the construction of the railway from Penrith to Keswick. The accompanying is an outline sketch

Fig. 67.



Outline of Dunmail Raise.

looking north from the south side of Grasmere Lake. It is situated between Steel Fell on the west, and Seat Sandal on the east. The former rises to a height of about 1,100 feet above the pass, the latter to a much greater elevation. Its culminating area is only about 720 feet above the sea. The small streams which run away from this area south and north, enter the pass at right angles, after flowing for a considerable distance down its eastern side. The former has its source partly in the peat bog to the north of Seat Sandal, and on its way makes a series of very beautiful cascades (scarcely at all known); its bed in some places consists of blood-red rocks, apparently jasperized sandstone. The latter, Birkside Gill, flows down the back of Helvellyn, and is a mere tributary to Wythburn brook, which has acquired its main volume *before* entering the pass on the other side. Farther north a stream from Helvellyn makes a series of the finest waterfalls at single leaps to be met with in the whole of the Lake District. Beyond this, Thirlmere occupies a considerable part of the pass. The cliffs on its western side are varied and picturesque, and the Raven's Crag is a grand and massive specimen of cliff scenery. Farther on, the pass bifurcates into St. John's Vale and the valley leading towards Keswick.

Among the elevated short mountain passes of the Lake District, may be mentioned Nan Bield, which leads out of Kentmere into Mardale; Black Sail, between Wastdale and Ennerdale; Scarf Gap, between Ennerdale and Buttermere; and Swirl Hause, at the head of Greenburn, Coniston Fells. The gap called Mickledoor combines the character of a narrow and deep rocky gorge with a high-level pass. The great 'rakes' on the southern side show that rains and frost, assisted by gravitation, have not been idle, though their tendency here, as elsewhere, has been to ruin and not to form the pass. One of these is called the Lord's Rake (already mentioned), and its ascent is one of the greatest feats a tourist can perform in the Lake District. The average depth of Mickledoor is about 500 feet. Taking it all in all, this upland gap may be said to combine, more than any other part of the Lake District, the characteristics of seclusion, altitude, towering and furrowed cliffs on each side, yawning abysses at each end, and grandeur in whichever direction the eye is turned. (See Fig. 38.) Among the most picturesque short passes in the Lake District may be mentioned the one between Blea Tarn and Great Langdale.

Origin of Passes.—Nearly enough has perhaps been said to show that the passes described, especially those with flat culminating areas, could not have been worn through or worn down by subaërial agency. We have no reason to suppose that the low ground at each end of a pass, or on each side of the ridge or table-land divided by a pass, originated after the pass was excavated. On the contrary, appearances would seem to point to the conclusion that the ridge or table-land was developed before the formation of the pass. In many if not most of the passes of England and Wales, the sides rise higher above the floor of the pass in the middle than towards each end.* In the middle, therefore, the amount of excavation must have been the greatest. To assume then that two streams, wearing their sources backwards, could have left the culminating level of such a pass, would be to assert that the streams achieved a maximum result where their action was at a minimum (as already hinted)—a species of reasoning which in any department of science, excepting geology, would not be considered worth a serious refutation. In most passes there is an area of a certain length where there is no stream whatever, and no excavation going on; unless we can invest the mechanical action of rain-drops with an excavating power on level ground. In these central areas the rain-water (where it is not directly absorbed) often gives rise to an accumulation of turf, peat, or marshy soil, which proves the absence of pluvial denudation. That the streams which flow along the lower parts of a pass have, at no former period, had a share in the excavation of the central or culminating area, is corroborated by the fact (of which many instances have been stated) that, generally speaking, they enter the pass sidewise at a lower level.†

* The middle is likewise often the widest part.

† The recent statement of Col. Greenwood, in the *Geol. Mag.*, that the streams on each side of a pass point their fingers towards each other across the summit-area, will not apply to any pass I have yet seen. In most instances the streams point their fingers away from each other as much as the

It would appear to have been overlooked that the streams which traverse a pass, instead of being its cause, may be its effects. Appearances justify the conclusion, that the streams would not have existed excepting for the pass. The pass forms a larger water-collecting or spring-developing surface than what, in the same area, could have existed before the excavation of the pass. But its sides, rather than its floor, must be regarded as the water-collecting surface, and the summits of the ridges by which passes are separated are the boundaries of their watersheds, rather than their summit levels. The streams which we see increasing in volume and excavating power towards the ends of a pass, have in many, if not in most instances, clearly imposed their channels on previously-existing sloping depressions. These depressions may be partly explained by reference to the reflux action of tidal currents during a gradual rise of the land, accompanied by wave-action. The pass itself is precisely the kind of excavation which would result from the action of great tidal and other currents, concentrated at moderate depths along the courses of previously-existing surface-undulations. The power of currents to excavate passes is disputed by few geologists,* and by no philosophers

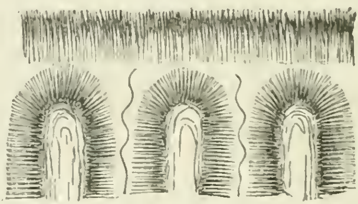
form of the ground will admit, as if to disclaim any conspiracy in the formation of the pass. It is impossible to survey even a wet high-level pass, such as that between Beckside and Harlock, Furness, with the assistance of a six-inch contour map, without seeing that the action of the small streams leaves the excavation of the summit area unexplained.

* Professor Jukes, the principal advocate of subaërial denudation, admits that marine denudation could have produced ravines and narrow winding valleys, 'as gaps or passes upon the crests of ranges of hills, when the neighbouring summits were islands, and the present gaps or passes were "sounds" or "straits" between them, traversed by strong tides and currents; and a narrow arm of the sea was thus made to assume a river-like action.'—*Quart. Journ. Geol. Soc.* June 18, 1862, p. 391. [All summits, however low their present level, were once islands, and all gaps or passes were once sounds or straits.]

who have made dynamical science a study. As regards short and straight passes, they may have been formed by currents, by waves, or by both. On our present sea-coasts, waves are every day busily at work in *breaching through* headlands and ridges, and breaking up main-lands into islands.

Origin of V-shaped Sloping Valleys.—If plains, flat-bottomed vales, ‿-shaped vales, longitudinal valleys and basins, transverse gorges, and passes are deducted from all the larger depressions in England and Wales, I believe a minority only will remain. We have now to consider the approximately V-shaped valleys or *ravines* which slope downwards sufficiently to give water

Fig. 68.



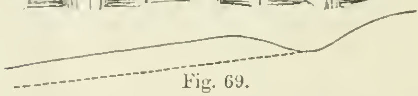


Fig. 69.

an excavating power, and which *shallow-out* upwards. Of these valleys a large proportion are connected at their heads by shallow transverse passes, as in Fig. 68, ground plan; Fig. 69, longitudinal section. This observation applies to many if not most of the valleys of Devon and Somerset. Easily-accessible instances may be seen to the W. of Teignmouth, to the N. and NW. of Taunton, on the declivity of the Quantock Hills, &c., and numerous instances may be met with in other parts of South Britain. The connecting passes may be regarded as a remaining part of the undulations of the surface, previously to the commencement of the action of the fresh-water streams by which the valleys have been partly, in most cases perhaps mainly, excavated. Of approximately V-shaped valleys shallowing-out and *narrowing-off* at their upper ends, there are not so many, of any considerable size, in England and Wales, as is commonly taken for granted. The reason, as already hinted, would appear to be that in our country there is not sufficient space for streams to acquire much breadth as well as depth of denuding power between watersheds and the sea, or between watersheds and plains. When streams reach a low level, their inclination of channel becomes too small to admit of much excavating power. At a high level they have not attained sufficient volume to give them much excavating power. The zone of *maximum* fluviatile denudation lies between the two, and in England and Wales this zone is narrow. True river-valleys, on a large scale, must be sought for in other parts of the globe, and there undoubtedly they may be found. Here the valleys which have really been mainly or entirely excavated by streams, with a few exceptions, are only to be found on the broad and continuous slopes of hills, or on the sloping sides of large valleys. They are generally narrow and are invariably V-shaped. In many cases, as shown by Mr. Maw ('Geol. Mag.' Vol. iii. No. 10, Oct. 1866), the stream may be able to maintain a channel, for greater or less distances, with sides, up to a certain height, steeper than those slopes above which result from the falling down of débris. But no atmospheric action can reduce the steepness of these slopes beyond a certain angle. In a state of dispersion rain has little power to reduce this steepness. In a state of concentration, rain produces lateral gulleys at intervals. In the softest and most incoherent rocks, the sides of the valley would slope at a comparatively low angle towards the immediate channel of the stream. In the case of hard and compact rocks the slope would continue at a high angle. In very hard and compact rocks the sides of the channel of the stream would retain their perpendicularity for an indefinitely long period. The dip of the rocks, and other conditions, would, in every case, affect the steepness of the sides of a river-valley, but it would never become a ⌣-shaped valley, and far less a flat-bottomed valley, apart from alluvial deposition. In the case of valleys in which the ground on each side of the channel of the stream slopes at a very low angle, and in which the rocks are hard and compact, the channel of the stream must be regarded as impressed on a previously-existing contour. In the case of most large valleys, not V-shaped, the ground on each side of a stream-channel is generally transversely level for some distance, and then it gradually rises upwards. To say that in such instances the actual channel was not the measure of the excavating power of the stream would be nearly as unwarrantable as to assert that the actual channel of a river, in a wide and level plain, was not the limit of its denuding action. Numerous examples of V-shaped valleys containing streams might be mentioned. How far they are due to the action of the streams can only be approximately determined by an examination of how far their sides rise continuously without abruptly terminating in a broad shallow ⌣-shaped valley, and how far their courses extend before giving place to flat-bottomed vales, or alternations of valley-expansions and connecting gorges. Generally speaking, where V-shaped wet valleys have been imposed on previously-existing depressions, the remaining part of the contour of these depressions can be clearly distinguished from the sides of the valley.

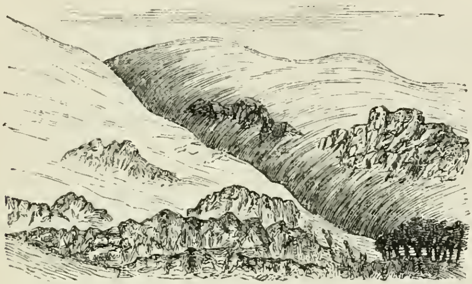
In many places, the wet V-shaped valleys would appear to have been excavated by streams along the courses of shallow transverse passes—the valleys afterwards widened and the upper parts of their sides rounded off by the sea—and since their emergence, deepened by the streams now flowing through them.* The wet valleys which have been *entirely* excavated by streams can scarcely be mistaken. There is a uniformity about their shape which can be explained by no other agency. Their bottoms, as already remarked, are very narrow, and slope longitudinally at an angle sufficient to give excavating power to running water. The brinks of their sides commence on ground, the former continuity of which must have formed a nearly flat surface.

V-shaped Gulleys of the Malvern Hills.—There would appear to be many dry, or nearly dry, short V-shaped valleys which could never have been excavated by fresh-water streams. They may be seen cutting through the escarpments of the Mendip Hills, and other limestone districts (see *Mountain Limestone Escarpments*), to which however, they are not confined. On the eastern slope of the Malvern Hills there are several striking instances. These hills are exceptionally dry. Nearly all the rain-water is absorbed, and but a part of it probably finds a vent at the base of the hills in the shape of springs. The hills are very much fissured; and as we have reason to believe in the existence of collections of water in the bowels of the earth through the heating of which metamorphism is partly if not mainly produced, we cannot be certain that a considerable part of the rain-water which sinks into the Malvern Hills may not find its way to a great depth. However this may be, it appears

* See *Excursions around Church Stretton and up the Gulleys of the Longmynd.*

obvious that the very narrow ridge of the Malverns could never have furnished a watershed for streams sufficiently powerful to have excavated the gulleys on their eastern declivity. The two most remarkable are the one near Lady Huntingdon's Chapel, Great Malvern, and the one behind North Malvern. The first, according to Dr. Holl, has been excavated in a mass of trap, the remaining part of which now forms the bottom and lower sides of the valley, while the bounding ridges consist of granite, gneiss, and mica-schist. It would appear to have been excavated by an agency assailing it upwards, as the detached cliffs chiefly look down the valley. In several places these cliffs exhibit passages or narrow inlets, from which blocks could not have fallen, but must have been abstracted in a way that can only be explained by the action of sea-waves. The valley in many places is filled to a certain height with angular detritus, a great part of which could not have fallen, but must have been gathered and left by the action of water. The more compact detritus is here and there covered by loose subaërial screes, with a distinct line of demarcation between the two. The valley may have been excavated by waves during a gradual fall or rise of the land. Trap dykes are now in course of being removed by the waves on many parts of the west coast of Ireland, leaving narrow gulleys. It can scarcely be assumed that the atmosphere may have acted more readily on the traps of the Malverns than on the adjacent igneous rocks, so as to originate the gulleys; for these traps are found, on the same hills, in dissimilar situations, sometimes forming projecting bosses. Professor Phillips, at the Birmingham Meeting of the British Association (1865), surmised that snow-water, towards the close of the glacial period, may have scooped out the Malvern gulleys, but the absence of a sufficient snowshed would be as much opposed to this theory as a deficient watershed would be opposed to the theory of rain-streams of adequate excavating power. Most of the Malvern gulleys widen at their upper end, and are more or less connected by terrace-shaped deviations from

Fig. 70.



V-Shaped Gulley behind North Malvern—Terminal Hill on the right; North Hill on the left.

the general slope of the hills. The valley behind North Malvern graduates at its upper end into a saucer-shaped cwm (already mentioned), from which there is a pass communicating with the western declivity of the hills. The bottom of this gulley is filled to a considerable height, and for considerable distances, with angular detritus, the greater part of which could never have fallen from the sides. (See Fig. 70.)

CHAPTER XV.

DENUDING ACTION OF FRESH-WATER STREAMS, RAIN, AND ICE.

Delineation of Streams on Shaded Maps.—The Ordnance Maps are wonderfully accurate in every respect excepting the exaggerated idea they give of atmospheric action. This, to a certain extent, is unavoidable; to some extent it might be remedied. To represent streams at all on the one-inch scale, the breadth of the lines, on an average, must be at least fifteen times the proportionate breadth of the streams. In transverse shading, the smallness of the scale, likewise necessitates the abrupt termination of the transverse lines against a stream which really flows along a ⊔ - or ⌣ - shaped valley. But in all the shaded Ordnance Maps I have seen, there is a manifest tendency to insert temporary rain-torrents as if they were permanent streams, and to make the ground appear as if it sloped uniformly towards every stream; so that the impression an Ordnance Map leaves on the mind of one not familiar with nature, is, that fresh-water streams are wearing down and running away with the land. The truth, however, is that, with the exception of true stream-valleys (which are not nearly so large or numerous in South Britain as in other parts of the world), the banks of streams are generally level or gently inclined for greater or less distances transversely, and that the immediate channels of the streams are the only impressions they have made on the general form of the ground. Contour maps, or maps longitudinally shaded, leave an impression very different to that conveyed by transversely-shaded maps. They reveal the fact that the majority of small streams, and many large ones, cross the contour lines. In other words, the contour lines only bend back to an extent equivalent to the direct or uniformly-continuous channels of the streams; and these channels, on the one-inch scale, are often too narrow to be represented at all, so that the streams appear to cross the contour lines at nearly right angles.

Facts showing the Limited Extent of Fluviatile Denudation.—That fresh-water streams have not done so much as is often asserted to excavate valleys will, I think, appear not only from what has already been stated, but likewise from the following facts :—

1. There are many instances of streams with considerable inclination of channel, which are often flooded, but which nevertheless have only excavated gutters of very inconsiderable depth. Such gutters, some of them only a few feet in depth, may be seen on the sides of the valley of the Dee, to the east of Corwen, and behind that town. They furnish the real measure of the denuding power of the streams, for the ground on each side is either transversely level (sloping only along the course of the streams) or *inclines away from the channels* of the streams on one or both sides. On the northern slope of Cader Idris, below the escarpment, I saw a stream running for a considerable distance along the summit of a ridge in which it had excavated a channel several yards in depth. Another instance of this phenomenon may be seen between Bethesda and Cwm Llafar, and many others might be mentioned, in all of which the channels on the ridges are not newly formed, but the continuations of the original channels of the streams. In the neighbourhood of Kirkby Stephen, on the mountain slopes, many

Fig. 71.

Transverse Sections of Valleys in Devon and Somerset, with the positions of Rivers.

ABF the Taw. C the Camel. D the North Teign. E the East Dart. G the Lyd.

powerful and good sized-streams furnished with every facility for denudation, and aided by rapids, and in many places by the pluvio-chemical solution of the limestone, have only cut channels V-shaped or ⊔ -shaped, varying from a few yards to a hundred feet in depth; and these channels, to which the ground on each side does not generally speaking incline, are distinct in their shape from the vast majority of valleys.

2. If we take a transverse section (horizontal and vertical scale equal) of a smoothly undulating country, we can see little distinction between the shape of a dry depression and a depression traversed by a stream or river. The latter in most instances, like the former, is merely a continuation of the general undulating surface. It seems impossible to explain this fact in any other way than by regarding the presence of the streams in the valleys as an accidental circumstance. The sections (Fig. 71), from Sir H. De la Beche's 'Geology of Devon and Cornwall,' will illustrate these remarks.

3. Many rivers, after flowing out of a large valley, traverse

a plain, and though they retain as much inclination, of course, and have acquired additional volume, they have not made a channel in the plain of more than a trifling depth. Instances: the Dee, in Llangollen Vale and Plain of Cheshire; the Ogwen, in Nant Francon, and between Nant Francon and the sea;* the Severn, in Montgomeryshire and Shropshire. The intelligent reader will be able to supply many other instances.

4. In many valleys the streams seem to be excavating their channels in drift which the streams themselves could not have accumulated. Some, if not most, of the Dartmoor valleys have been partly filled by boulders of granite (away from the areas consisting of hard spheroidal masses in a soft granitic matrix), among which the streams have a great difficulty in making a channel. As they work their way downwards, boulders smoothly rounded, and sometimes polished, become successively exposed, in situations where the streams themselves could never have worn them by attrition. In the lower part of the course of the stream which runs under Ivy Bridge Viaduct, the channel is choked up with rounded boulders, many of them very large, which, through want of force in the stream to move them, occupy the same positions for an indefinitely long period.† Mr. Kelly, the eminent antiquarian of Yealmpton, who is almost as familiar with some of these stones as with the faces of his own family, has assured me that they

* This is a remarkable instance. Nant Francon has been excavated across the strike of a variety of hard rocks. The Ogwen at its bottom has so little inclination of channel as to admit of the growth of peat Between Nant Francon and the sea, the excavating power of the river is much greater, though it has not made a channel more than from 5 to 20 yards in depth.

† The power of flooded torrents to carry large stones any distance has been overrated. The late Principal Forbes, in his *Tour of Mont Blanc*, assures us that the debacle of the Val de Bagnes in 1818 moved great blocks only very short distances.

have not moved an inch during the last twenty or thirty years. But it is at a place called Yealm Steps (so far as I have had an opportunity of observing), that the phenomenon of a stream struggling among previously accumulated boulders is most strikingly manifested.* In Wales, Shropshire, Yorkshire, Lancashire, &c., the bottoms of river-valleys, as well as riverless valleys, have been filled to a certain height with undoubted marine or marine-glacial drift. The rivers, since its accumulation, have been labouring to make channels by carrying the finer parts of this drift away, and sporting with its boulders. In many places the rivers have got through the drift, and have succeeded in channelling the rocks below. This shows the limited action of the rivers since the drift was deposited, and while it throws doubt on the pre-glacial power of rivers to excavate large valleys, it reveals the commencement of the process of channel-making by a river, and shows that its effects are distinct in shape from the majority of valleys.

5. If all valleys have been excavated by rivers, we should expect to find some traces of river-gravel more or less rounded at various heights on the sides of the valleys (and this after making all due allowance for the effacing action of rain). No *certain* traces of such gravel, distinct from marine or marine-glacial drift, have yet been found at more than trifling elevations above the present river-channels.

Turbidity and Transparency of Rivers.—In England the turbidity of many rivers during rains is mainly owing to the washing-in of soil from arable lands, and

* In the valleys of Dartmoor, fresh-water streams are re-rounding the upper surfaces of these boulders, but those of them which have been removed by man, often show their under surfaces smoother than their upper.

cannot be taken as a measure of the denuding power of fresh-water streams in general. The Severn, and other rivers, in the lower or middle parts of their courses, are often turbid during rain, while nearer their sources their waters are transparent. Many of the Welsh rivers which are bordered by no arable land are wonderfully transparent during the heaviest rains, as I have noticed in the case of the Mawddach, near Dolgelly. It is true that rivers may convey a considerable amount of certain kinds of very fine matter in solution without their transparency being very much affected; but it is still true—taking rivers in general—that their denuding power in rocky districts must be measured by the turbidity of their waters.

Denuding power of Rivers not to be measured by the Quantity of Matter they carry to the Sea.—I think that a little consideration will show that all attempts to measure the denuding power of rivers by the quantity of matter they carry to the sea, must prove deceptive, unless the channels of the rivers from their mouths to their sources consist of solid rock.

As regards England and Wales, I think it may be safely asserted, that at least nine-tenths of the matter carried by many rivers into the sea is marine, or marine-glacial drift, derived from the drift *in situ*, or from places where it has been reassorted by the rivers. This remark will apply to the Severn, and all those rivers the direct channels of which have been mainly cut in boulder clay, or marine shingle and sand.*

* Since the MS. of this work was sent to the publishers, a writer in the *Quarterly Review* (April 1869, pp. 377, 378) has arrived at conclusions similar to those above expressed, and has even gone farther than I have done in mainly limiting the denuding power of rivers, during intervals between submersions, to their removal of marine drifts. The coincidence, on this subject, between his views and my own, is very remarkable.

Rivers not planing Agents.—Rivers cannot plane down a land-surface, and rains cannot leave anything but slopes varying in steepness according to the materials acted on, but in all cases slopes. The channel of the Severn is exceedingly uneven, especially between Bewdley and Iron Bridge. A bargeman, who had been familiar with it for more than twenty years, corroborated my own observations by assuring me that the channel of this river consists of ridges, projecting rocks, and deep pools—the unevenness arising from both excavation and deposition—the latter giving rise to ridges of shingle at intervals. Near Llangollen the Dee tries hard to rut up its channel of Wenlock shale, and to leave as uneven a surface as is compatible with the nature of the rocks.*

Mode and Extent of Fluviatile Deposition.—A minute examination of the courses of the rivers of England and Wales will, I think, show that rivers (as already observed), deposit or heap up pebbles in small ridges crossing their channels obliquely or at right angles, or leave accumulations in lateral recesses; and that they are incapable of spreading out pebbles continuously over great areas, so as to form extensive pebble-flats, large and smoothly-swelling knolls at the bottom of valleys, or long expanses, terraces, or plateaux of pebbles along the sides of valleys; that rivers alternately denude and deposit within small areas; that they cannot, unless exceptionally, mix up sand, clay, and pebbles, leave stones standing on edge or end, select a number of large pebbles or small pebbles, and leave them in pockets; or to any considerable extent deposit beds or patches of sediment and gravel in

* Where strata of uniform composition are transversely inclined to the course of a river, it may peel them off laterally, so as to leave a valley-plain with an escarpment on its lowest side.

vertical succession; that during their ordinary action their capability of moving stones to great distances is very limited; that the transportation of pebbles during river-floods is confined to the courses of currents; and that extensive deposits with flat surfaces are limited to fine sand, clay, or loam, with few or no pebbles of any size; that rivers, unless on a very small scale, and that very exceptionally, cannot give rise to oblique, waved, alternately denuded and deposited, and complicated lamination, like that resulting from the action of oceanic currents.

Retrogressive Excavation by Waterfalls.—That waterfalls, under a continuance of very favourable conditions, may recede so as to excavate or deepen the channels of streams, is undeniable. But it does not follow that every waterfall at the inner end of a ravine has worn back the ravine by its retrogressive action. Where the rocks, in vertical section, are of nearly uniform denudability, the stream can only undermine to such a limited extent as to allow the abrasive power of the upper part of the fall to gain the ascendency, so as in course of time to convert the fall into a rapid, and the rapid into an inclined channel. Where, as is the case in the limestone districts of Yorkshire, the lower stratum yields readily to the undermining action of the waterfall, the latter may recede and still retain its abruptness as long as the favourable conditions last. But in many of the ravines of England and Wales in which waterfalls occur, an examination of the structure and arrangement of the rocks, I think, will show that the falls have only receded very short distances. In some ravines they do not appear to have receded at all, or at most not more than a few feet, since their action commenced. The stream tumbles over a nearly perpendicular wall of rock, many times longer than the breadth of its channel above and below; and on the brink, or in the face of the wall of rock, it has made little or no indentation. The well-defined narrow channel above and below shows that it has not wandered from end to end of the wall of rock. Instances of the apparently accidental connection of waterfalls with precipices* may be found in a waterfall about one and a half mile south of Newtown, Montgomeryshire, and Aber waterfall,† Carnarvonshire. Even in the Llanrhaiadr ravine, Denbighshire, the highest waterfall in Wales (Pistyll Rhaiadr, said to be more than 200 feet high), does not seem to be exerting an undermining power, though the conditions are less unfavourable to retrogressive excavation than in many instances which might be named.‡ The water here falls over a cliff consisting of interstratified felstone and slate, according to Professor Jukes. (See Fig. 72.)

Fig. 72.

Pistyll Rhaiadr.

* An explanation of this connection may be seen on our present sea-coasts, where streams tumble over the inner precipices of creeks or coves. In those cases where waterfalls do excavate their way backwards on sea-coasts *th y have a sea-cliff to begin with.*

† The Aber falls over the north-west wall of a mass of felspathic porphyry, by which the adjacent slate has been altered into quartzite and porcellanite (Ramsay). Previously to the excavation of the Aber valleys, which to a great extent coincide with faults, the porphyry probably lay buried under slate or other sedimentary rocks.

‡ Cautley Spout, on the eastern side of the Howgill Fells near Sedbergh, falls over a crag which cannot be regarded as the head of a ravine. It is

River-channels of South Britain compared with those of other Countries.—If no instances of valleys undoubtedly excavated by rivers existed in any part of the world, we might be justified in trying to explain the ⌣-shaped valleys of this country by fluviatile action. But in the very deep and narrow gorges of the Alps, and more especially in the cañons of the Rocky Mountains, we have river-channels of enormous depth compared with their width—their width being often little greater than that of the river, and their sides nearly or quite perpendicular. If the sides of these river-channels have not been bevelled down by atmospheric action, is it reasonable to regard ⌣-shaped British valleys as bevelled down river-channels? more especially as many of the latter have been excavated in rocks equally calculated with the former to withstand atmospheric action? In our own country we have many true river-channels differing from those of other countries only in size. These channels (as already stated) are often impressed on ⌣-shaped valleys, and often on plains. Unless the influence of rain and frost in our own country can be shown to be almost infinitely greater than in those parts of the world where extremely deep and narrow river-channels exist, there would appear to be no way of escaping from the conclusion that the action of streams in England and Wales has only produced direct river-channels, or at most steep-sided V-shaped wet ravines. The attempt to evade this conclusion by appealing to the increased altitude of British mountains in glacial times, and the increased width of rivers resulting from the greater extent of watershed, will be seen to fail when we consider that the same

probably the highest waterfall in Great Britain—its whole height having been calculated at 860 feet. The highest of the three cascades takes a leap of at least 400 feet.

distance between the lines of watershed and valleys must have existed as at present; that only a trifling increase in the inclination of river-channels could have resulted from the bodily upheaval of the British area to an altitude which rendered only the German and Irish Seas, the English Channel, and a part of the Atlantic, dry land; that the principal action of rivers in England and Wales—supposing them to have been increased in volume by an extension of watershed—must have been on existing sea-bottoms, where few or no traces of valleys have been detected; that such supposed favourable conditions to an increase of river-action must have been of comparatively short duration.

Theory of former Increased Fluviatile Action.—Mr. Prestwich and others, seeing the difficulty of explaining the breadth of many valleys by existing river-action, have had recourse to the theory that during the breaking up of the glacial conditions which once prevailed in the north-west of Europe, and the melting of ice and snow, the rivers must have acquired a great increase of volume and consequent breadth of excavating power. But supposing we admit such a temporary increase in the size of rivers, the limitation to the volume of water imposed by the small extent of snow-shed, would still render it disproportionate to the breadth of the vast majority of our valleys, while the shape of many valleys does not resemble a river-channel, however large its dimensions. The question, however, may be asked, at what time did the breaking up of the glacial conditions occur? It could not have been immediately before the glacial submergence, for very intense cold must have continued until England and Wales were deeply submerged, as is evident from the quantity of ice-borne drift which became distributed over the bottom of the sea, and which is now found extending up to great altitudes among our mountains. It could not have been after the period of the glacial submergence, for the marine-glacial drift then deposited is still found lining our valleys; and since then no streams, flooded or not flooded, have effaced the glaciated rock-surfaces, which in many places reach down to the lowest depths of the valleys, and approach to within two or three feet of the present channels of rapid torrents. (See *Excursions from Coniston.*) If the theory be limited to the removal of quantities of drift from valleys by rivers swollen through the melting of ice and snow after the glacial submergence, it leaves the question of the original excavation of the valleys where it was.* It may likewise be remarked, that in supposing a former period or periods of increased fluvial or pluvial action, and the existence of certain conditions more favourable to denudation than at present, the fact ought not to be left out of consideration that the agency of man, in removing trees and grass, has in recent times facilitated both rain and river action to such an extent that in the majority of instances (in England and Wales) in which we see water in a turbid state, the turbidity can be

* Since the above was written Mr. A. Tylor, F.G.S., in the *Quart. Journ. Geol. Soc.* for Feb. 1869, has proposed the theory of a 'pluvial period,' during which the amount of rainfall was so very much greater than at present, as to be capable (with the assistance of rivers) of excavating valleys, filling them up to a certain height with gravel, and distributing gravel over wide areas. He has overlooked the fact that the gravels of the valleys of the greater part, if not of the whole of England and Wales, are principally marine or glacial drifts; but he justly remarks that 'after the heaviest rainfall in recent times, there is not a sufficient force of water to remove vegetation, so as to make any change in the present surface;' and the circumstance of his having recourse to an 'opening of the windows of heaven,' or a pluvial flood of water, is another instance of that yearning after *breadth and efficiency of cause* which will exist as long as geology engages the attention of rational beings. The present state of geological opinion shows clearly that linear atmospheric denudation, or the action of streams, will not explain the principal phenomena of the earth's surface.

traced to a road, path, arable field, or ground recently divested of grass or trees.*

Action of Rain-torrents.—At intervals, in hilly countries, particularly in Wales and the Lake District, torrents occasioned by the 'bursting of thunder clouds' acquire a volume and amount of excavating and transporting power almost transcending belief. They sometimes denude more in the course of an hour than the ordinary action of rain-streamlets or rivers would in a century. For information on this subject we are unfortunately obliged to depend on local traditions, histories, and guide-books. The Mow Cop headland, on the borders of North Staffordshire, has, within the memory of man, been the scene of one of these subaërial cataclysms. The north-west side of the Stiper Stone ridge was severely visited some years ago, but I could obtain no information relative to the effects of the flood on the hill itself, though I learned from Mr. Davies, post-master, Minsterley, that a part of the village narrowly escaped destruction. On the east side of Nant Francon the lower or more rubbly part of the high rocky slope has evidently been a number of times subjected to temporary rain-floods, in addition to land-slips. Pennant tells us of the 'bursting of a thunder cloud' causing a torrent of stones to rush down the above-mentioned slope. The mass of ruins divided into two before reaching a house, which in consequence was saved.† In the Lake District, the stream called Liza, in Ennerdale, once became so swollen during a thunderstorm,

* The denudational capacity of temporary streams in hilly districts is often greatly increased by their making channels of roads.

† The Rev. Mr. Williams, Rector of Llanberis, informed me that he has been an eye-witness of the excavation, by temporary rain-torrents, of several striking gutters on the steep slaty slopes forming a part of the south-west side of Llanberis Pass.

as to equal the Thames in breadth. In 1760, at midnight, a tremendous waterspout (?) occasioned a torrent which rushed down a ravine between the mountains called Grasmoor and Whiteside, carrying along with it all loose materials. It swept over the valley below, and a piece of arable land at its entrance, peeling the whole surface and leaving the rocks bare. The transported matter, on being deposited, covered a space of ten acres. By the channel the torrent left it would appear to have reached the dimensions of 300 feet wide, and from 15 to 18 feet deep. It uprooted a solid stone causeway, supported by an embankment, which it not only swept along, but in its place excavated a fresh channel.*

In Hutchinson's 'Excursion to the Lakes' we find the following account of a flood which happened on August 22, 1749, in the Vale of St. John's:—'The clouds discharged their torrents like a waterspout. The streams from the mountains uniting, at length produced so powerful a body as to rend up the soil, gravel, and stones to a prodigious depth, and to bear with them mighty fragments of rocks. Several cottages were swept away from the declivities where they had stood in safety for a century. The vale was deluged, and many of the inhabitants, with their cattle, were lost. A singular providence protected many lives. A little school where all the youths of the neighbourhood were educated, at the instant crowded with its flock, stood in the very line of one of these torrents; but the hand of God, in a miraculous manner, stayed a rolling rock in the midst of its dreadful course, which would have crushed a whole tenement with its innocents; and by its stand, the floods divided, and passed on this hand

* I examined some of the effects of this catastrophe in 1864, on walking from Crummock Water to Lorton.

and on that, insulating the school-house, and leaving the pupils with their master trembling, at once for the danger escaped, and as spectators of the horrid havock in the valley. . . . It is thought to have been a spout or large body of water, which by the lightning incessantly rarefying the air, broke at once on the tops of the mountains. . . . During the violence of the storm, the fragments of rocks which rolled down the mountain choked up the old course of this brook [Catcheety Gill], but the water forcing its way through a shivery rock, formed a chasm four yards wide, and about eight or nine deep. The brooks lodged such quantities of gravel and sand on the meadows, that they were irrecoverably lost. Many large pieces of rock were carried a considerable way into the fields; some larger than a team of ten horses could move, and one of them measuring nineteen yards about.'

Y-shaped Rain-gutters.—In many parts of Wales, but more especially, so far as I have observed, on the sides of the valleys traversed by the railway between Rhayadr and Llanidloes, we may see newly-formed small gutters which have evidently been scooped out by temporary rain-torrents. In all cases, however, they resemble the letter V in vertical section, and are never ◡-shaped, or ⊔-shaped. Considerable-sized V-shaped ravines, resembling the letter Y or T in ground plan, may be seen on the south side of the valley of the Severn, between Llanidloes and Newtown; on the north side of the eastern part of the Kerry Hills; on the north-west escarpment of the Stiper Stone ridge, &c. The last mentioned ravines will be described in *Excursions* (from Shrewsbury to the Stiper Stones).

Action of Rain on Heaps of Coal-mine Rubbish.—On walking, some time ago, between Wolverhampton and Willenhall, I was struck with the form of surface communicated by rain to artificial table-lands, ridges, and mounds of débris. The *commencement* of the action of rain could be seen, and one could safely speculate on the inequalities rain is capable of producing. I did not observe a single instance in which rain had excavated a distinct miniature ravine, without having first flowed over a sufficient extent of watershed to enable it to acquire a concentrated and linear form of action. The ravines invariably shallowed out and narrowed off at their upper ends. They were always V-shaped in vertical section, and the effect of lateral pluvial action was to produce lateral gutters, and not a uniform bevelling down of the sides of the ravines. It would be difficult to find a better illustration of Professor Sedgwick's doctrine, that atmospheric denudation takes place in lines. The ravines were models of those true river-valleys which have nothing to do with longitudinal valleys, transverse gorges, and passes. The rubbish, in some places, had been thrown down at intervals, so as to include many forms of stratigraphical structure as regards dip, alternating softness and hardness, &c.; but nowhere could I see any sign of the commencement of a longitudinal valley, or of an escarpment, or cwm, so far as the 'wash of rain' was concerned. In some places, however, both escarpments and cwms could be seen resulting from a totally distinct agency, namely, the interference of man. Where the rubbish had been undermined by spades, or where slips, produced by external causes, had occurred, there short escarpments and shallow cwms began to show themselves. But both these phenomena were evidently distinct in shape from the channels of the rain-torrents.

Diffused Action of Rain.—Except on arable land, and soft deposits of earth, sand, clay, or mud, bared of vegetation, rain cannot be said to act mechanically in a state of dispersion, and even under these circumstances it can only acquire a transporting power worthy of being noticed by becoming concentrated into runlets. On surfaces well protected by vegetation, rain can only act effectually where there are facilities for its forming channels in which it can exert some amount of laterally-undermining power. On solid rocks, rain can only act effectually after it has become concentrated into streams charged with solid matter, so as to invest it with an abrading power. Mr. Darwin says, 'there is good evidence that pure water can effect little or nothing in wearing away rocks,'* a remark I think still more applicable to fresh than to salt water, so far as mechanical action is concerned.

Chemical Action of Rain.—The chemical action of rain-water may, under favourable conditions, dissolve certain kinds of rocks, such as chalk, mountain-limestone, &c.; but the extent to which limestone can resist the influence of rain, forces us to the conclusion, that dissolution to any perceptible extent can only take place where the rain-water is retained for a shorter or longer period. The preservation of glaciated rock-surfaces affords an undeniable proof of a limited atmospheric action, and the most delicate glacial markings are often to be found on limestone.†

Perpetuation of Smoothed, Rounded, Hollowed, and Grooved Surfaces of Limestone Rock.—Geologists have too hastily taken for granted that the chemical and me-

* *Origin of Species*, p. 283.

† I lately noticed that the intensely polished, and very finely striated limestone surfaces near Baycliff (west coast of Morecambe Bay) were, during a great part of the year, subjected to the action of rain-water, probably more or less charged with humus. This water flows between the limestone and a bed of lower boulder clay, and has probably continued to flow since the surface of the boulder clay became dry land.

chanical action of rain-drops can smooth, round, hollow, and groove limestone, granite, and other rocks. From a series of observations, a full account of which would be out of place in this work, I have been led to conclude that the chemical and mechanical action of rain (before it has gathered into a stream of sufficient size, and sufficiently charged with solid matter to exert an abrading or grinding influence), can only *roughen* rocks (see *Origin of Rock-Basins*), and can in no case produce a regularly-shaped surface, excepting where such a surface lies concealed in the structure of the rocks, and becomes merely developed; that rain cannot leave a surface which cuts through, instead of following, inequalities in the composition or structure of rocks; and that consequently it cannot give rise to regularly-smoothed, rounded, hollowed, curvilinearly-perforated, or curvilinearly-grooved surfaces. Such surfaces are very common at high as well as low altitudes on the Mendip Hills, Somersetshire; near Minera and Llandudno, Denbighshire; on Birkrigg Common, Furness, and more or less in all limestone districts. They often go by the name of rock-work. The fact that on Stainton Common, Furness, and elsewhere, smoothly basined and grooved surfaces may be found on the under sides of enormous limestone boulders transported during the glacial period, shows that they must have been formed before the close of the glacial submergence; and the identity of the forms of these surfaces with those exposed to the atmosphere on the summits of the neighbouring hills, shows that the latter have withstood atmospheric action since they rose above the glacial sea.*

* On examining the pavements and curbings of pavements of streets, we can soon convince ourselves that all regularly-smoothed surfaces (structural developments excepted) are the result of the grinding influence of solid matter, and not of mere water. Where flags and stones, in railed-off

Preservation of Lithodomous Perforations.—In the neighbourhood of Torquay, as first shown by Mr. Pengelly, borings made apparently by mollusks in limestone, may be found at altitudes greater than 200 feet above the present sea-level. On examining some of these borings, in May 1867, near the summit of Asheldown, north of Kent's Cavern, I discovered that the minute circular striæ (similar to those believed by most conchologists to be the effect of the rotation of the shell, by which an ornamental finish is given to the perforation) were in many instances perfectly preserved. Since then Mr. Darbishire, F.G.S., of Manchester, has found what he believes to be numerous *Pholas*-borings, not only on the Little, but on the Great Orme's Head, at heights up to 570 feet above the sea.* I lately found groups of these perforations on the stones of a loose heap (evidently derived from the neighbourhood), near the summit of the Great Orme's Head. Many of them were more than three inches in length. Very lately (January 1869), I found similar perforations 667 feet above the sea, on the eastern side of Hampsfell, near Grange, Lancashire.†

corners or unfrequented recesses, are only exposed to atmospheric action, they merely become roughened; when brought in contact with boots, shoes, wheels of vehicles, &c., they are smoothed, rounded, and hollowed. In the pavements of Dawlish and Teignmouth, the limestone egg-shaped pebbles are either left intact or roughened by rain in the untrodden parts, while in the thoroughfares they are smoothly cut down to a nearly uniform level. The smooth grooves in flags under house-spouts become roughened by rain-water. Artificial granitic basins under roadside spouts, become roughened by the falling water, but were a number of small stones to be placed in the basins, they would enable the falling water to preserve or increase the smoothness of their bottoms. (See Article by Author in *Geol. Mag.* vol. iv. No. 7, July 1867.)

* *Mem. Lit. and Phil. Soc. of Manchester, Session* 1867–68. 4th vol. 3rd series.

† These perforations cannot possibly be the work of rain, because they generally occur on the protected sides of rocky ledges, or blocks to which rain can have no access; because they completely ignore the unequal com-

Denuding Action of Ice.—So much has been written on this subject, that a very few brief remarks must suffice in a work chiefly devoted to the results of personal observations. Professor Ramsay has satisfactorily shown that there must have been a period of continental land-ice, succeeded by a period of submergence and floating ice, the latter followed by a period of valley or district glaciers. The lower part of Llanberis Pass, on the sides of the lakes, has almost everywhere been smoothed and rounded by ice. A great part of the upper end of Nant Francon has been planed down and smoothed by the same agent to a striking extent. In many other parts of Wales, *roches moutonnées*, striæ, and other signs of glacial action, do not require to be sought for, but obtrude themselves on the observer's attention. In the Lake District glaciated rock-surfaces are likewise numerous. One of the finest detached roches moutonnées I have yet seen is near the middle of Great Langdale. In the chapter on the origin of Cwms I have somewhat fully considered the effects of district glaciers in elevated situations. The traces left by icebergs and floating-ice have likewise been referred to in various parts of this work. The effects of the great flow of continental land-ice cannot be so easily deciphered as those of district glaciers, though among the Coniston Fells I lately ascertained that the principal glaciation, including *roches moutonnées* and striæ, must have been produced by a flow of ice ignoring hill and valley, and that valley glacial moraines, apart from

position of the limestone rock; because their forms are circular, smooth, regular, and of uniform pattern; because they show circular striæ and other signs of having been ground out or bored out; because they occur in groups, often in compact limestone, the surface of which all around is smooth and continuous, &c., &c. If they are not the work of any living animal, they must have been produced by an extinct variety or species of borer.

drifts, were comparatively absent or ill-defined. (For observations on the distinction between the effects of general and district glaciation, marine drift, moraines, and screes, see *Excursions from Coniston.*)

Mutually Preserving and Destroying Power of Ice and Water.—Little notice has hitherto been taken of the fact that both ice and water *preserve* and *destroy* the forms of surface subjected to their action; preserve by deposition, destroy by denudation; and this would appear to be the reason why, in certain places, traces of the above three glacial periods have been preserved, while in other places they have been destroyed. I believe that the great flow of continental ice must have smoothed and rounded the outlines of many of our lower hills, both by denudation and deposition, left glaciated rock surfaces on a magnificent scale, and may have curved back slaty laminæ;* that icebergs and other forms of floating ice must have likewise left glaciated rock-surfaces, reduced the height of ridges, deepened previously existing hollows, indented the sides of hills, and transported erratic boulders; that glacial sea-waves and currents must have widened and deepened previously-existing depressions, terraced the sides of hills, made lines of cliff, left rocky projections of various shapes, detached and deposited local drift, and redistributed erratic drift; that valley glaciers must have modified the previously twice modified surface by denudation and deposition, and that more or less distinct traces of all these modifications have been preserved. The Rev. O. Fisher believes that the ground was finally moulded into

* See paper by the Author, read June 1867 (*Quart. Journ. Geol. Soc.* vol. xxiii. p. 323. In the neighbourhood of Gupworthy, Brendon Hill, West Somerset, the bending back of the laminæ is on so extensive a scale as to point to the long-continued action of a great flow of continental ice, or to the grazing force of grounding icebergs. It amounts to an apparent reversal of dip.

its present form by a second great flow of continental ice during a supplementary glacial period preceding the age of (now) submarine forest growth.* If so, I think its action must have been very superficial, and limited to the upper portion of drift accumulations.

Glacial and Marine Denudation Compared.—The power of ice (leaving the question of its date out of consideration) to denude the earth's surface cannot, I think, be disputed; and the denuding power of great bodies of salt water set in motion by earthquakes, submarine convulsions, or submarine volcanic eruptions, is equally incontrovertible. If, therefore, the denuding power of ordinary sea-waves and currents should eventually be found insufficient, I can see no resource left for the denudationist who infers the NATURE OF THE CAUSE FROM THE FORM OF THE EFFECT, and who is convinced that in geology time, strictly speaking, means nothing, but to take refuge either in a stupendous progression of a crust of land-ice many thousand feet in thickness, grinding, crushing, uprooting, transporting, and depositing, as it moved heavily along; or in bodies of water set violently in motion, by causes more or less unknown; at one time sweeping clean the path of denudation, at another, leaving débris in peculiar situations.

The present state of the denudation controversy seems to justify our predicting that the main burden of denudation will soon have to be divided between an ocean of water and an ocean of ice, causes equivalent in the breadth of their operation to the breadth of the phenomena requiring explanation. As yet, I think that by far the greatest share of the burden must be thrown on the sea, and that there are many difficulties in supposing it to have been borne by ice. All will at

* *Geol. Mag.* vol. iii. No. 2 (Nov. 1866), and vol. iv., No. 5 (May 1867).

once agree to the doctrine of great down-planings of uptilted strata by the sea; but that the sea must have mainly given rise to the inequalities of the earth's surface, so far as they are the result of denudation, will, I think, appear from the following facts and considerations, which, from the complicated and general nature of the subject, cannot be very precisely stated:—The quantity of rock removed by the sea greatly exceeds that removed by rains, rivers, and ice. More than two-thirds of the earth's surface are under the sea at any given time. The shape of the greater part of the bottom of the sea has, therefore, been formed by the sea. As nearly a third part of the earth's surface, constituting dry land, sinks slowly* down through the zone of waves and currents (the latter ordinary or paroxysmal), which is at least 1,000 feet in vertical extent, and rises slowly up through the same zone, marine agency must be sufficient to obliterate the forms of land surface left by rains, rivers, and ice; and as more than two-thirds of the whole surface are either acted on by the sea, or by the sea preserved from subaërial action, it follows that the greater part of the land surface at any given time must present the form given to it by the sea. The sea can obliterate (by denudation and deposition, if not by denudation alone) forms of land surface much quicker than subaërial agents can produce them. These agents require so comparatively long periods to give rise to new forms of ground, that the greater part of the land-surface at any given time must retain the principal features impressed upon it before it rose above the sea. The only way in which it would seem possible for the subaërialist to attempt to escape from these considerations would be, by asserting that the area of England and

* *Slowly* is not here intended to exclude the idea of a *number* of sudden downfallings and uprisings.

Wales has been quite exceptional in continuing above the surface of the sea, while numerous and extensive oscillations in level have affected the general surface of the earth. In answer to this it may be remarked that the main forms of the ground in South Britain (cwms perhaps excepted) are characteristic of every region of the globe.*

* Until very lately it has been the belief of all geologists that the amount of marine denudation greatly surpasses that resulting from fresh-water; and subaërialists have acknowledged that in comparison to the huge and 'continental' denudations, and removals of rock by the sea, 'the present irregularities of the earth's surface are mere scratches' (Mr. Whitaker, *Geol. Mag.* for Oct. 1867). Some recent attempts, however, have been made to controvert this idea, but were it consistent with our limits, I think it could be easily shown that these attempts are far from being successful. (See p. 275.)

BOOK III.

EXCURSIONS, WITH GEOLOGICAL AND MISCELLANEOUS OBSERVATIONS AND REFLECTIONS.

BOOK III.

EXCURSIONS, WITH GEOLOGICAL AND MISCELLANEOUS OBSERVATIONS AND REFLECTIONS.

[A number of districts remarkable for certain kinds of natural scenery, or for combinations of different kinds of natural scenery, are here selected, that phenomena considered separately in the preceding book may be viewed in connection. Many districts, some of them, perhaps, as instructive as those here introduced, are necessarily omitted.]

I.—FROM MINERA TO LLANGOLLEN BY WAY OF THE WORLD'S END—AN EPISODE IN THE GEOLOGICAL HISTORY OF LLANGOLLEN VALE.

In May, 1865, on calling at the office of the Minera Limeworks Company, Mr. Jones, the manager, very obligingly offered to be my guide over the small limestone table-land which lies to the west. This upland plain has been cut into two by denudation, in all probability following the course of a fracture. A brook now flows through the dividing gorge, but as the latter is open at both ends, there is no necessity for supposing the brook to have been the main excavator, more especially as currents must have rushed through this gorge when the marine drift, farther south, was in course of being deposited. On the north side of the gorge, the table-land presents a rocky floor, with wonderfully regular rows of limestone flags separated by rents. They looked like an immense assemblage of grave-stones; and as we proceeded in our examination, we found that they were not without inscriptions of a kind that revealed more eloquently than words the nature of the denuding cause which must have formed this natural cemetery. The inscriptions were not mere random impressions, but regular, smooth, and curvilinear grooves, generally more or less parallel. I believe that waves wielding stones, or ice charged with stones, and moved to and fro by waves, must have been the sculptors employed in fashioning the many thousands of grooves which are here crowded within the narrow compass of a few acres.* Before reaching the farther edge of the table-land, I had resolved on walking to Llangollen over the moor, instead of going back to Wrexham, and returning by rail. I soon found that the brook which ran through the gorge did not enter it in a straight line, but, as is common with brooks as well as rivers, made a sudden bend, as if the gorge had diverted it from its previous course. I walked up the channel of the brook in a direction at nearly right angles to that of the gorge, and saw a phenomenon very common in Wales, namely, a brisk stream running down the declivity of the ravine, without having excavated any channel farther than was necessary to contain its waters. Farther on we reached a smaller natural graveyard of sculptured limestone slabs, which was probably at one time much more extensive. The imposing Lower Silurian ridge of Cyrn-y-brain now appeared on the right. On the left and in front, a moor sloped gently towards the west, until it merged into a pass running

* See article by Author in *Quart. Journ. Geol. Soc.* vol. xxiv. No. 95, p. 277.

NE. and SW. along the base of Cyrn-y-brain. Our way lay along the south-east side of this pass. The moor soon became more or less boggy, and after parting company with Mr. Jones, I lost my way through trying to travel in a straight line, but this afforded an opportunity of seeing the extraordinary havoc committed by the brook already mentioned in the upper part of its course. An enormous mass of drift was in several places cut down to a great depth. The commencement of the channel of the brook in this drift was well defined.

On returning to a solitary miner's cottage, I was directed along a cart road, which eventually led to Llangollen. The limestone rock was buried beneath a covering of fine shingle with a matrix of clay. Many of the pebbles appeared as if they had been very much rolled. Being without a map, and fancying that the cart road was roundabout, I turned to the left, and on walking over a heath-clad eminence, I soon descried the figure of a man at some distance. It turned out to be a shepherd, a Scotchman, who very obligingly conducted me to the World's End. At first I thought he might possibly be an undeveloped Hugh Miller, but as the distance from any house, or any other human being, increased, and I fancied he was leading me in a wrong direction, I became somewhat suspicious, a circumstance I have ever since regretted. But it was about the time when the newspapers were filled with cases of garroting. We passed a deep circular cavity lined with loose stones. Whether they had been thrown in by human hands, or left by eddies in the glacial sea, I had not time to consider. It was probably a swallow hole (a subject on which it is very easy to broach unorthodox ideas, or to be out of the geological fashion), and the Scotchman informed me there were others in the neighbourhood. The thought of the possibility of my being thrown into one of these funnels, and left to become enclosed in a stalagmitic coffin, did not then cross my mind; but as my guide led me still farther, as I perversely supposed, out of the right path, and down into what might be called a lonely valley, were it not that loneliness everywhere reigned triumphant, I could no longer resist being afraid of him, though I now believe he was as innocent a Scotchman as ever crossed the border. His object had been to take me the nearest way to the World's End, but he at last agreed to let me have my own way. We therefore approached the World's End not directly but from one side. Very few tourists visit this spot, though it is sometimes the scene of picnic parties from Llangollen. I know but of two other World's Ends in South Britain. There is one (and who would have thought it?) among the Berkshire Chalk downs. It may be very pretty, but I do not think it can be sublime.* There is another near Church Stretton, in Shropshire, under the shadow of the Longmynd, but as it is a pass traversed by a road which leads somewhere, it cannot be strictly called a World's End. There may be many others; but of all the World's Ends in the world, this is perhaps most like a World's End when approached from Llangollen. It is completely shut up at its inner end by a high limestone cliff. A stream of water enters it, not by falling over the cliff, but by gushing out of a subterranean channel under the cliff. As I entered the World's End (for the Scotchman had returned to look after his sheep), the impression it produced can never be effaced. The valley is very narrow; on one side the slope is very abrupt, with craggy projections of Lower Silurian rock. Several brooks rush down ravines in this slope with great impetuosity,

* I have since heard of a World's End, a few miles from Reading—a public-house on the Bath road, now, however, extinct.

and in some places form picturesque cascades. Their murmurings are the only sound by which the intense solitude of the World's End is usually broken. These lateral ravines are genuine specimens of the effects of fresh-water excavation. On this side the slope is richly wooded, and the crags partly concealed by foliage. On the other side, the whitish-grey cliffs of Eglwyseg, at intervals plumed with vegetation, rise above a talus of angular stones more or less covered with grass. Farther on towards Llangollen the cliffs rise, tier above tier, to the height of at least 800 feet above the bottom of the valley. (See *Limestone Escarpments.*) In the valley I noticed several trap boulders, which were probably brought there by floating ice. In course of time I came in sight of the remarkable transverse gorge which forms the outlet of the longitudinal valley into which the World's End graduates. (See *Longitudinal Valleys and Transverse Gorges.*) Instead of following the gorge into the parallel longitudinal valley called Valle Crucis, I proceeded in the direction of Castell Dinas Bran, with the limestone cliffs still towering on the left, and slopes of Wenlock shale rising on the right.

Castell Dinas Bran is one of the most thoroughly detached eminences in the kingdom, and yet it is not a mass of trap rock, or different from the subjacent strata, excepting on the north or Eglwyseg side. It has been circumdenuded without the denuded parts—at least, on three sides—having been softer than the hill itself. The action of waves and currents, ordinary or intensified, sparing it merely because it accidentally lay out of their direct course, furnishes the only rational explanation. As is well known, it is crowned with the ruins of an ancient castle. But the geologist will prize it chiefly for the prospect it affords of a varied assemblage of monuments of denudation, including, within a small compass, every form of natural scenery, excepting the semicircular cwm. Between him and the Eglwyseg cliffs he can look down into a dried-up sea-strait. To the west he can see both longitudinal valleys and transverse gorges, with which the connection of the River Dee is apparently accidental. South-west, the shallow concavity in the face of Barber's Hill seems as if it had been sliced out by a gigantic scythe. Eastwards he can see the Vale of Llangollen debouching into the great plain of Shropshire and Cheshire, which stretches away without any apparent boundary, like a petrified ocean.

An Episode in the Geological History of Llangollen Vale.

There is one spot in the Vale of Llangollen which, in many respects, is unequalled in Great Britain. It is immediately to the south of the town. On the west is the steep heath-clad eminence called Barber's Hill (already noticed), on the east a richly-wooded knoll; immediately around there is a plateau covered with luxuriant vegetation. The prospect towards the north embraces the conical peak of Castell Dinas Bran, and the truly magnificent tiers of the Eglwyseg limestone cliffs at a greater distance, but still sufficiently near to appear in some states of the weather as if they impended over the intervening vale. A small brook flows through the plateau just mentioned, in which it has cut a deep channel, in most places overhung with wood. In some parts the channel is strewn with pebbles mixed with large boulders,* in others the bare flaggy rocks

* The lower part of the course of this brook is choked with boulder drift (many of the boulders very large), the surface-level and inward limits of which are well defined. In one part of this drift the brook has made a grand display of its denuding power.

make their appearance. During heavy rains the brook swells to the dimensions of a river; makes a sublime uproar, and speedily alters the face of nature, so far as its immediate jurisdiction extends. To live in such a spot, out of sight of the habitations of man, and beyond the hearing of the voice of strife and revelry, might well be the desire of any elevated mind, especially after experiencing the hollowness of the pleasures of fashionable life; for a nearer approach to a terrestial paradise can scarcely be conceived. Such a wish was realized in this very spot towards the close of the last, and during the first half of the present century. The two 'Ladies of Llangollen' (sufficiently celebrated to render any particular account of them unnecessary) * lived for forty years in a cottage, the architecture of which corresponded to the character of the scenery, in the centre of this romantic corner of Wales. A great part of their happiness arose from contemplating the extremely varied scenes which are here crowded within the compass of two or three miles. They were constant observers of the changes produced by the brook a few yards behind their dwelling, the sound of which they could easily hear by day, and still more impressively during the silent watches of the night, especially after a thunderstorm, and its accompanying deluge of rain. For nearly half a century these ladies communed with nature, and the God of nature, in this scene of retirement, but in common with the less ethereal part of the human race, their sun sunk beneath the horizon of time, and the story of their romantic and secluded life faded into a dream.

As the contemplative traveller now visits the cottage,

* Lady Eleanor Butler and Miss Ponsonby settled at Llangollen about the year 1789, and died, one in 1829, and the other in 1831. Lady Eleanor was daughter of the 16th Earl of Ormonde and Ossory.

which is fast hastening to decay (June, 1866), and reflects on what once transpired within its walls, he is more than ordinarily impressed with the evanescence of all earthly enjoyments, even when they are the least earthly in their nature. Dinas Bran still rears its ruin-crested summit to the clouds; the Eglwysegs still frown in their primeval majesty; the trees around the cottage still 'flourish fresh and fair;' the 'brawling' brook still flows in its old channel, and during a flood, undermines its banks, and reassorts its pebbles; it still keeps up the same incessant murmur, increased to a roar as the rain-flood drenches the neighbouring slopes. But the episode in the geological history of Wales, which once embodied itself in the midst of all this permanence, has dwindled into a vision which now seems like a pale cloud fast approaching the horizon of human forgetfulness.

We must not, however, overlook the fact, that though the peaks, cliffs, woods, and streams of Llangollen are enduring compared with the evanescence of man, they, too, are destined to change; and should the sea again overflow this part of Wales, and the Vale of Llangollen again become a bay, then the story of its occupation and cultivation by man, including the above episode, would merge into a dream in the retrospective survey of an intelligence sufficiently long-lived to have been a silent spectator of the whole series of events. Vain are the longest periods of time, or rather the longest are the same as the shortest, for it is only eternity that a mind framed in the image of an Eternal Being can contemplate without melancholy forebodings of an end.

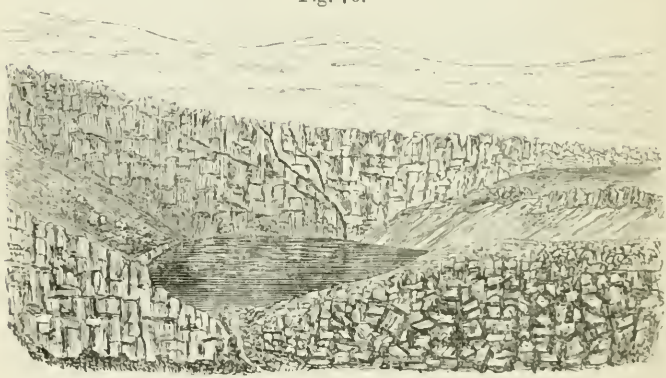
II.—FROM CONWAY TO LLYN DULYN.

'By all means see Llyn Dulyn,' said an artist who had spent much of his time in sketching the wilder features of the Welsh hills. I was then in Bangor, and had, a few days before, been within a mile of the back precipice of this lake-basin, during a roundabout ascent of Carnedd Llewelyn. I afterwards took it from Conway. It is difficult to reach from any town or village. The route from Conway is perhaps the most varied and instructive, though not so short as across the hills from Aber or Llanfairfechan. After getting out at Tal-y-Cafn Station, a few miles from Conway, and crossing the river by the ferry, it is necessary to be careful not to get entangled in a perfect network of Welsh lanes, which one is sure to do if he attempt to reach Llyn Dulyn in a straight line. It is best to keep along a footpath not very far from the river,* until you pass a church; then take a lane to the right, get into the road leading to Glan Dulyn, and thence to Llanbedr, from which the cart road to the neighbourhood of Llyn Dulyn can easily be followed. I took the quarry road to Cwm Eigiau, along the south side of the brook, and did not leave the road for Llyn Dulyn till I had nearly reached the end of Llyn Eigiau, my object being to ascend to the hill in front of Llyn Dulyn, to make a sketch. I had been informed that the lake lay in a very deep basin, but I scarcely expected to have to ascend nearly all the way to the rocks called Clogwyn Eira before I could see much of the water. On afterwards descending in a direct line to the lake, I had several fine views of Melyn Cwm and its llyn.

* Between the river and Glan Dulyn, there is a great thickness of drift containing more or less rounded stones of porphyry, greenstone, &c., many of them large, and, so far as I could see, most of them striated, or in some way glaciated.

One is disappointed with the surroundings of Llyn Dulyn, but perhaps the lake-basin itself is the most wonderful in South Britain. It has, I believe, no beach, excepting a very little at the outlet. The bare rock, in most places, plunges at once into the water. The back wall does so almost perpendicularly.* It is, strictly speaking, a lake-pit. It is reported to be 300 feet deep, though this may be an exaggeration. The precipice behind may be 500 or 600 feet in height—I do not think higher. The frontal barrier of the lake rises speedily

Fig. 73.



Distant view of Llyn Dulyn, looking down from opposite hill.

from the narrow outlet to a height of from 150 to 200 feet. From an examination of the outlet it would appear that the whole depth of water is dammed up by solid rock, which probably rises higher than the level of the lake on the right, though concealed under detached stones which seem to run down under the water. Many of the stones consist of a kind of rock which, for want of a more correct name, may be called brecciated felspathic porphyry. It contains lumps of slate, &c., imbedded. Near the lake I saw a split block, con-

* This wall has been rutted by two small streams.

siderably rounded, at least 30 feet long by 11 or 12, and another 20 feet long. I could see no satisfactory indications of glaciation, though they probably exist. Blocks reaching 20 feet in length, with smaller ones, occur in groups, as if they had been dropped by floating masses of ice. They extend as far as a mile to the east of the lake, and rest on a great mound of boulder drift. This drift consists of more or less rounded as well as angular stones, as may be seen in sections exposed by brooks. At some distance from the lake the drift becomes finer, and on the steeper slopes, graduates, as usual, into a chip and splinter drift. (See *Origin of Cwms and small Lake-basins.*)

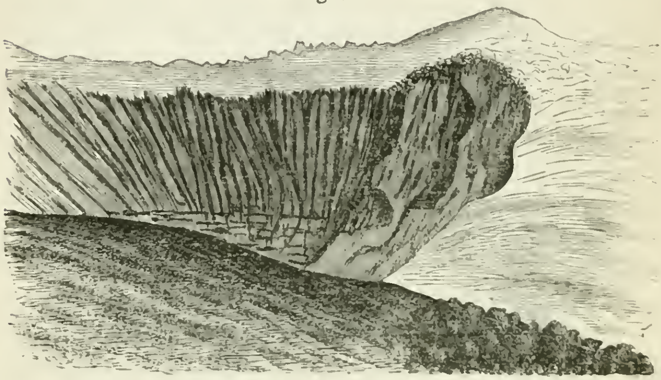
III.—FROM BETHESDA TO CARNEDD LLEWELYN, AND BACK THROUGH CWM LLAFAR.

It is impossible to direct the tourist how to find his way through the labyrinth of lanes to the south-east of Glan Ogwen, miscalled Bethesda. He must trust to himself and his compass, and if he has to cross the brook Caseg several times, he will be compensated by the sight of the miniature ravines it has excavated out of the boulder drift, some of which are very picturesquely concealed by rich vegetation, contain rapids and cascades, and are choked with disinterred large stones, either moss-covered or presenting the smooth and polished surfaces given to them while rolling in the glacial sea. Higher up the course of the brook, and beyond the habitations of man, the evidences of the former sojourn of this sea in the valley of the Caseg become irresistible. The brook has cut a distinctly-marked channel in a great plain of marine drift which stretches up into Cwm Caseg. To prevent becoming immersed in peat bogs, it will be necessary for the tourist to keep to the left of the brook. After reaching the mouth of the V-shaped valley of the Wen, I ascended its southern slope till I reached an elevated shallow pass above Clogwyn yr helwyn, the flat bottom of which was so thickly covered with soft peaty turf as to suggest the question, If rain raises the level of passes by accumulating vegetable matter, how can rain act as an excavator of passes? I think it cannot be denied that on all the approximately-flat surfaces of Snowdonia, rain acts more as a conservative than a destroying agent. I crossed the head of the eastern branch of Cwm Caseg at the risk of rolling down to the bottom, and soon after commenced the direct ascent of Carnedd Llewelyn. The mountain is a mass of detached rocks and stones, both *in situ* and displaced. In shape it is a transversely nearly flat ridge, which rises from both ends towards a flat stone-strewn summit. It is a strip of table-land with abrupt precipices on both sides. On the SE. you look down over a concave line of cliff into Cwm Llyffaint. This line of cliff commences all at once, and might soon be overstepped by one ignorant of the peculiarities of Snowdonian scenery. It is a fac-simile of a sea-cliff, and at one time must have been exposed to the unmitigated fury of ice-laden billows. On the NW., you look down over a wall of greenstone into the deep recess containing Ffynnon Caseg, bounded on the other side by very rugged cliffs, surmounted by the peak called Yr Elen. Before asserting that this upland recess must have been a quiet harbour during the glacial submergence, we ought to consider that the swell of the Atlantic from the north-west must here have found its way, supposing the directly local winds to have been comparatively powerless to awaken billows. In such recesses the blowing up of water above the neighbouring sea-level, and its consequent backward rush, generates a form of denuding agency peculiarly calculated to scour out cwms.

From Carnedd Llewelyn I descended by the nearest way into the upper part of Cwm Llafar. The small streams run down the sides of this cwm in such a way as to indicate that they are the effect and not the cause of the cwm. The small springs which originate them occur in positions showing that they have been developed through the excavation of the cwm, and not that they have excavated the cwm. I believe this remark applies more or less to all cwms, especially large cwms. At the head of Cwm Llafar, there is a concave wall of greenstone, resting on Caradoc strata. In the process of being worn back, the peak of Carnedd Dafydd has narrowly escaped destruction. On stepping a few yards from the crowning pillar of stones, towards the north, a person might very soon loose his footing, so as to be precipitated over the above wall of rock. A Birmingham Scripture-reader, some years ago, fell over a part of this wall, and was found after a prolonged search by a body of workmen from the Penrhyn slate quarries. The precipice, a little to the east of the peak of Carnedd Dafydd, commences very abruptly, and is very nearly perpendicular. For more than half its height it is perfectly mural, with the exception of a number of small vertical furrows and three gaping rakes. For height, breadth, and rocky continuity it is perhaps the finest precipice in Wales. It forms the inner termination of the large valley called Cwm Llafar, on the south-west side of which there are several rough and rugged minor cwms, in one of which there is a pyramidal mass of rock.

The bottom of Cwm Llafar is covered with a great thickness of marine drift, which, as Professor Ramsay long ago showed, has been partly ploughed out by glacial action. A great part of the drift is evidently the underminings of the cliffs which bound the cwm on the south and west. At a distance of about a mile from the head of the cwm the prospect on looking up is truly sublime. The great greenstone precipice appears more columnar than before, and the gashes on the

Fig. 74.



Cwm Llafar and Carnedd Dafydd, from hill behind Bangor.

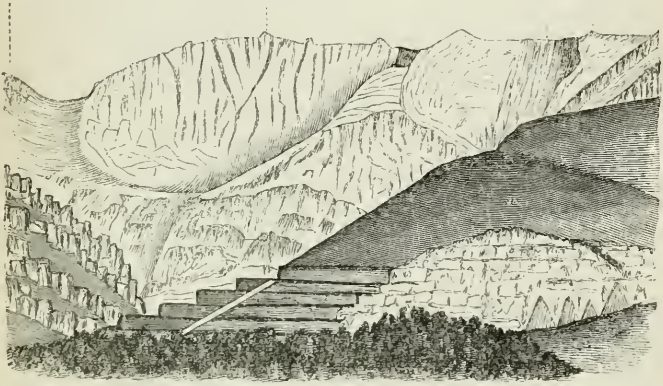
south-west side of the cwm seem more profound. In the foreground a cascade adds variety and beauty to one of the finest conceivable pictures of wild mountain scenery.

IV.—FROM BETHESDA TO NANT FRANCON, LLYN BOCHLWYD, AND LLYN IDWAL.

The east side of Nant Francon is a steep rocky slope at least 2,000 feet in height. It is very wildly turretted, furrowed, and wreck-strewn. It exhibits no cwms, strictly so called. But the upper part of the western side has been hollowed out into at least five well-marked cwms, exclusive of Llyn Idwal. These cwms are well situated for having been left by land-slips, but there is no indication of any slipped land underneath any of them, and few outscoopings of any kind at a lower level, excepting a delta under No. 4, which may not have come out of the cwm. Most of them contain glacial débris.

Cwm No. 1 (nearest the Penrhyn slate quarries), has been excavated obliquely to the stratification. It contains a small stream, nearly dry in summer. No. 2, likewise excavated by a cross-denudation: slates dip S. at about 45°. No. 3, a fine rather flat-bottomed smooth cwm. The stream below it—not in it—has made an unsightly gash. It is a double cwm with a connecting pass. No. 4, much rain-rutted, with stream of débris

Fig. 75.



Nant Francon, from the hill behind Bangor.

and light-coloured earth; rain here infringing on the previous form of ground; a glaring rain-rut in the grass-covered detritus below. This detritus runs from the mouth of the cwm down to the base of the slope, where there is a delta. Rain could not have deposited the detritus on so steep a slope, though rain has perhaps formed the delta out of it. It contains no stream whatever (June 1868), though a stream is marked on the Ordnance Map. The cliff at the upper end is continuous, and talused with earth and screes. No. 5, double and very deep. I had not time to notice it particularly. It looks down on Llyn Idwal. (See *sequel*.)

Before reaching the picturesque bridge over the Ogwen, I noticed that many bosses of rock presented smoothed faces looking *down* as well as up Nant Francon, showing that all the smoothing had not been done by descending glacial action. On the south side of the lake, the rocks have not only been rounded, levelled, and smoothed by ice, but likewise smoothly hollowed out by the sea in places, such as transverse fissures, where ice could not have exerted much grinding power. Minute basins and protuberances may be seen all along between Llyn Ogwen and Llyn Idwal. Apparently sea-worn, continuous and straight cliffs (not horizontally corniced), with cleanly-swept bases, may be seen on the east side of Nant Francon, near its upper end.

Llyn Bochlwyd.—On walking along the south shore of Llyn Ogwen, a gentleman who was indulging in the truly innocent recreation of rowing along its gently-rippled surface, called me by name, and he proved to be the proprietor of the 'North Wales Chronicle.' A short time afterwards we agreed to go in search of Llyn Bochlwyd by the nearest possible route. On reaching the top of one slope, about 300 feet in height, we saw a formidable-looking escarpment between us and the mouth of the cwm, with a small purple strip of the sublime summit of Glyder Fach above it. We knew the lake lay between the two, and commenced the ascent in right earnest. The slope was quite 40°, and a considerable part of it bare rock, more or less smoothed by an upwardly as well as downwardly-moving agency. On reaching the level ground above, at a very considerable height above the level of Llyn Ogwen, one of the most extraordinary scenes Snowdonia affords suddenly burst on the sight—a cauldron-shaped hollow, strewn with stones, and rising gradually on three sides to the base of a semicircular precipice of bare rock, at least 800 feet in height. This precipice forms the abrupt northern face of Glyder Fach and the high plateau called Y Waun Oer (the chilly mountainous flat, Pennant). The height of its brink above the lake cannot be less than 1,400 feet. It may be seen from the hill behind Bangor, and from Beaumaris. It is a truly magnificent concave wall of rock, broken only by a striking series of Y- and W-shaped indentations, for which the English language supplies no appropriate name, but which perhaps form the most solemn feature of cliff architecture—solemn not merely in appearance, but in the silent testimony they bear to the lapse of time. As seen from a distance, the smooth faces of rock which partly compose the precipice, glisten with a silvery lustre in the sun's rays, while the intervening fissures and furrows are plunged in awful shadow.

The immense accumulation of stones in front of Llyn Bochlwyd occupies such a position as it would have done had the sea excavated or enlarged the cwm.* The stones are continued down a depression in the frontal declivity, in a stream—not two lateral streams or one stream of much breadth, as if left by glacial action, but as if accumulated on the lowest ground by retreating waves. The cwm was obviously scooped out block by block, and stone by stone, not grain by grain; and its form is, at the same time, irreconcilable with the idea of the blocks merely falling away from a receding cliff. Screes now result from the dilapidation of the cliffs bounding Cwm Bochlwyd, but not one of the stones in front of the lake could have *directly* fallen from the cliffs. It is highly probable that the remaining stones and débris are not nearly all that were scooped out. The finer detritus may have been carried far away.

* It is crested with glacial débris. (See *Origin of Cwms.*)

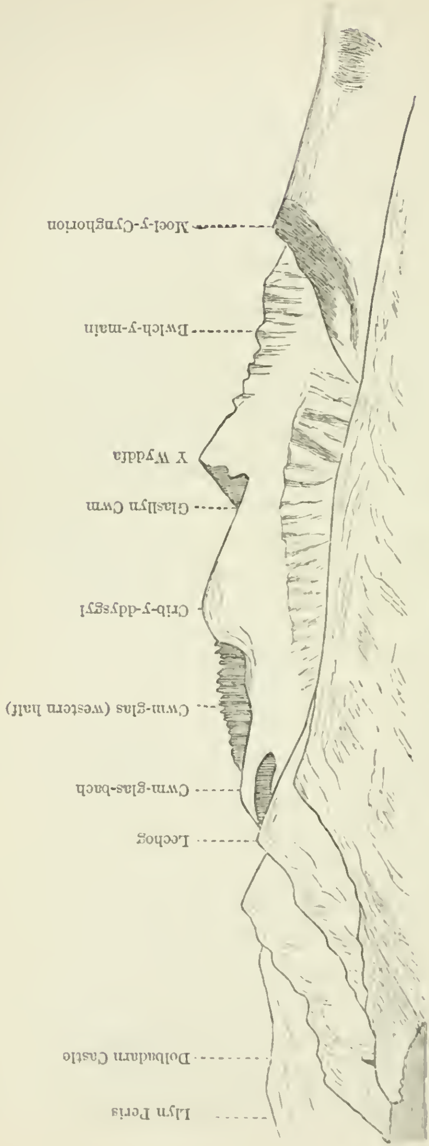
Llyn Idwal.—From Llyn Bochlwyd the descent, in a nearly straight line, to Llyn Idwal, is not difficult. For a considerable distance in front of Cwm Idwal, the flatness of the ground shows that neither land-slips or rain could have formed it. Here, as elsewhere, the question arises, If rain-torrents made such an excavation, how has the present brook made only a narrow channel? Cwm Idwal must have been excavated by an agency capable of acting on level ground. It looks very like an irregular sea-coast cove, surmounted by vacancies left by coast-slips. Around it the slopes are more or less cliffed. At the bases of those cliffs which have not been swept clean, there are either loose screes or grass-covered fine detritus. These cliffs must, therefore, have been once steeper than now. There is a stream of débris with large stones between the outlet of the passage called Twll du, or the Devil's Kitchen, and the lake, but this stream has apparently come chiefly from the south side of the outlet. The runlet which flows through the Kitchen could not have transported such large stones. Cwm Idwal embraces rather more than half a circle. It is very rough, but in the main curvilinear. It has been excavated irrespectively of the structure of the rocks. On the south-west side oblique denudation has revealed a fine section of the dip of the strata towards the Twll du synclinal axis. Cwm Idwal may be regarded as excelling every other cwm in Snowdonia, so far as the observer finds himself closely hemmed in by precipices which combine the most sublime with the most horrific forms, varying from slanting faces of rock and magnificently-fluted cliffs to vast towering rock-masses furrowed by the elements, and here and there hollowed out into shapeless recesses, which often appear so darkly shaded as to throw a sombre air over this temple of Nature. Of the size of this natural temple some idea may be formed from the fact that the south wall slopes up to the summit of Glyder Fawr, a height nearly 2,000 feet above the surface of the lake.

The stream from Llyn Idwal has nowhere worn very much of a channel, and scarcely any at all on rushing over the rocky slope called Benglog, where one would suppose it has had a capital opportunity. The Ogwen brook has likewise here done very little. The brink of its small channel is sharply defined, and on each side of it, for some distance, there is a *transversely-level* surface of glaciated rock. The question is not, Could the Ogwen in time wear down a valley as deep as Nant Francon? but, Could a brook which, since the Glacial Period, has persisted in making, and succeeded, in spite of the chemical and mechanical action of rain, in keeping up a ⊔ -shaped channel little more than its own breadth, ever give rise to a ‿-shaped valley, at least three hundred times its own breadth?

V.—FROM BANGOR TO SNOWDON BY THE LLANBERIS ROUTE.

The road lay along the bottom of an old strait which stretches from Port Penrhyn, near Bangor, to Port Dinorwic—its length being about six miles. It is certain that brisk tidal currents once ran in and out of this narrow valley. At Bangor railway station there is a deposit of false-bedded sand, pebbles, &c., which is resumed a little farther south, and runs for a considerable distance along the right-hand side of the valley in the shape of a level terrace; and in one place traces of smaller terraces may be seen on the slope above it. The escarpment on the left hand is a good specimen of an old coast-line, cliffed at intervals. Lower Bangor

Fig. 76.



North-West View of Snowdon, from near Llanddeiniolen.

lies under the steepest part of it. Towards the other end, where the valley unites with the present Menai Strait, there are several forlorn islets with passages between and small cliffs at intervals. A part of the bottom of the valley is swampy and peaty.

A little distance beyond Port Dinorwic the road lay along a plain partly covered with drift containing large rounded stones of indirectly local derivation. From a rising ground, the north side of Mynydd Mawr appeared as if it had come in for an unusual share of concave scarping, and forcibly suggested the question, What power, in earth, sea, or sky, could have assailed the original rounded forms of the Welsh hills in such a way as nearly to eat their hearts out, and produce a maximum degree of disfigurement?

All around Dolbadarn the rocks (quartz porphyry, Cambrian grit and slate), have retained their smoothly-glaciated surfaces, and where the planing icy agent could not gain access, as in the recesses and fissures, especially on the lee or north-west side, the rounded hollows and prominences left by the sea are equally apparent; though at a time when congealed water is all the fashion, the action of water in its ordinary state is liable to be overlooked.

On ascending Snowdon by the Llanberis, or most frequented route, a number of cwms present themselves on the south-west side of tbe valley; a large one under Moel Elia, and several farther to the south-east. Their levels vary, and their floors slope more or less downwards. One of them, to the north-west of Moel Goch, is very deep, and overhung by high and almost black cliffs. Another, on the north side of Moel-y-Cynghorion * looks as if a plano-convex slice had tumbled

* It was over the eastern cliff of this hill, and not over Snowdon, that the Rev. Mr. Starr, of Northampton, fell. He was ascending from Llyn Cwellyn

out of the hill-side. The distinction between these cwms and the smooth sides of the valleys seems as marked as between the skin-covered flesh and a ruthless gash, though in some cases this may be chiefly in appearance. A smooth-sided and ⌣-shaped short valley, covered with grass, terminates in a pass or col called Bwlch-y-Maescwm. Was this valley excavated by the agency which so unceremoniously made incisions in the faces of the adjacent hills?

A long time before reaching Clogwyn du'r Arddu (porphyry, partly columnar, with bands of slate, contiguous to faulted felspathic ash, and resting on greenstone) the very imposing form of its dark cliffs formed an appropriate vestibule to the towering rock-masses of Y Wyddfa. They consist of extensive surfaces of rock, bedded and cleft at various angles, with screes at their bases which would seem to have chiefly found their way along the 'rakes,' at the bottom of which they form deltas of small stones. Immediately under this line of cliff is the basin of the small lake Llyn du'r Arddu; north of this hollow a terminal moraine, 2,250 feet above the sea; still farther north a smooth and flat area consisting of marine drift, which apparently runs under the glacial débris. That the cliffs were mainly formed by the sea cannot, I think, be doubted. The cliff-line runs nearly straight for a considerable distance. It occupies a position where the sea may have marshalled its full force, and carried on the work of cliff-making by the removal of blocks as well as smaller detritus. The face of the cliffs down to their base shows that they were left, not by trituration, but by a more powerful process.

valley, and probably did not expect so sudden a transition from a smooth grass-covered slope to a rugged precipice. He was arrested in his fall by projecting rocks. Mr. Griffith Ellis, of Llanberis, who found part of his remains, gave me a correct account of the accident.

Ice, either coast-ice or glacial-ice, or both, has modified them, and probably rendered them less perpendicular.

From Llyn du'r Arddu the ascent becomes suddenly steeper, and continues steep until the back or western declivity of Crib-y-ddysgyl is reached. Very soon the peak of Snowdon may be seen rising, not as almost every other peak rises, but curving round the south-western brink of Glasllyn Cwm, in the shape of a promontory which, at first, appears only a few yards wide, shooting up into the sky, and terminating in a precipice nearly perpendicular.* Were it not for the existence of the road, and the knowledge that the ascent is perfectly safe, a tourist unaccustomed to Alpine climbing might at first feel timid. The back of the peak is a continuation of the steep western declivity of the mountain. It is thickly strewn with stones lying at all angles, and diversified by rocky pinnacles *in situ* (volcanic ashes and strata of Bala age nearly vertically cleaved). On arriving at the summit the geologist is much more interested by the view immediately beneath him than by the prospect of distant objects. The *look down* into Glasllyn Cwm, if unanticipated, can scarcely fail to inspire terror. The spectator finds himself within two or three feet of the brink of an almost continuous wall of rock, from 1,200 to nearly 1,600 feet in height, in some places quite perpendicular, and seldom at a less angle than 70°. The assistant of the proprietor of the summit refreshment rooms pointed out to me the spot, marked by a white stone, whence Mr. Williams, the botanical guide, was precipitated a few years ago. He had previously resolved not to descend the north-east slope of Snowdon any more; but an unexpected call on filial benevolence induced him to make another and a fatal attempt. His body was caught in its fall by projecting rocks, and

* At an average angle of about 70°.

recovered with great difficulty. Down to the spot whence he fell the declivity from the pillar of stones is only about 45°. It then descends to the bottom almost vertically. From the bottom the floor of the cwm slopes down into Glasllyn.

It is easy for members of the Alpine Club to depreciate Snowdon because it can now be ascended on horseback; but the mountain, though it has lost much of its romance, still retains all its grandeur. It will ever surpass most mountains in Europe, and every mountain in South Britain, by its unique form, consisting of a headland rising wildly to a point only five or six yards in breadth, with really terrific precipices on two sides (the left hand and in front), and a stone-strewn and pinnacled slope to the right at an angle of 45°. On looking down this slope towards Cwm-y-llan, the spectator can see to a vertical depth of about 1,900 feet. In front the depth to the ridged buttress called Lliwedd, by which the base of the peak is propped up, is about 1,000 feet. On the left, as already stated, the depth ranges from 1,200 to nearly 1,600 feet. The sketch (see *Frontispiece*), was taken in 1868, when the prospect behind the Lliwedd buttress was involved in mist. The mist nearly filled Cwm-y-llan, and seemed to boil up to the brink, whence it recoiled, leaving the rocky edge called Bwlch-y-Main distinctly visible. On walking along the brink of the cliff towards the narrow part of this edge, and looking down on the rolling sea of mist, the tide of which occasionally ebbed so as to permit several hundred feet of the rugged precipice to appear beneath, the impression received will never be forgotten.

On returning from the peak of Snowdon, I deviated a little from the road, near Clogwyn du'r Arddu, towards the right, in order to see Cwm Glas. It is a double-headed cwm nearly a mile in breadth. Its floor consists of more or less smoothed and rounded rocks. The farthest division, bounded by Crib Goch, with its bare red rocky peak, columns, and pinnacles, presents about as wild a scene as can well be conceived. The wall which separates Cwm Glas from Glasllyn Cwm on the south, is in many places the merest edge; and in the sight of this and other edges with their underlying cwms, one is often constrained to ask the question, Was it a slow process of decay that wore out these yawning abysses, and revealed the gaunt skeleton of Snowdonia, only concealed by narrow strips of the original smoothly-swelling contour of the mountain? or was it the fellest power of ocean, propelled in particular directions, that made these deep incisions into the grass-covered slopes, by a combined process of undermining, battering down, tearing out, and sweeping away? In Glasllyn Cwm, the excavating power has been so merciless as nearly to divide Snowdon into two. Its inner wall has been cut back far beyond the axial ridge of the mountain, which is now only represented by the narrow promontory of the peak, and the highest part of Crib-y-ddysgyl.

On taking a farewell glance of the amphitheatrical gashes, with abrupt and fresh-looking borders, which form so striking a contrast to the generally rounded and flowing contour of the Snowdonian hills, I think that an unbiassed mind cannot resist the impression that these gashes were not principally made by atmospheric agency. It seems plain that rain-streamlets and brooks, in various positions, as on both sides of Llanberis Pass, and below Cwm-y-Clogwyn, are only capable of forming narrow ⊔ - shaped or V-shaped gulleys, the ground on each side of which retains its former configuration. It seems equally plain that where land-slips have occurred, there is more or less of a rubbish-heap, or representative of the slipped land, underneath; while the majority of the larger cwms, as is evident from the shape of their floors and foreground, could not have resulted from land-slips. (See *Origin of Cwms*.)

VI.—FROM LLANBERIS TO SNOWDON THROUGH THE PASS, AND BY LLYN LLYDAW.

Taking it all in all, the finest rocky scenery in Wales may perhaps be seen during a walk from Lower Llanberis or Dolbadarn to the summit-level, or Pen-y-Pass Inn, and thence along the miners' road to the top of Snowdon.

Lee-side smoothing of Rocks.—Before leaving the shores of Llyn Padarn, it may be well to notice not only the traces of glacial action, but of the former sojourn of the sea. The rocks (quartz porphyry, Cambrian grit and slate) in many places are smoothed, rounded, and hollowed on too minute a scale to be explicable by the action of ice. The small and deep hollows and rounded protuberances are often on the lee-side (or the side looking down the valley), where glacier-ice, even admitting a sufficient degree of plasticity, could have exerted very little force. They have evidently been smoothed by an agency assailing them from the NW., which must have been the windward side during the glacial submergence. About the middle of the Pass of Llanberis, beyond the toll-gate, and before arriving at Pont-y-Gromlech, a rocky ridge has been principally smoothed on a large scale from the NW., or up the pass. At the upper end it is rough and cliffy, excepting towards the summit. It may have been smoothed by an iceberg or icebergs floated up the pass by oceanic currents. In the Pass of Llanberis, and other parts of Wales, there are instances of so-called *roches moutonnées* with roughly-scarped bases. Instead of the scarping having been produced by weathering after the glaciation of the bosses, as Professor Ramsay believes, I think that, in many cases at least, it must have been the effect of the undermining action of the sea before or after the upper part of the bosses were rounded by floating ice. Atmospheric action could not have made cliffs along the bases of bosses surrounded by approximately-flat ground.

Low-level Cwms.—Before leaving the flat part of Llanberis Pass, it may be instructive to take notice of a number of shallow cwms, or amphitheatrical recesses, with *level floors* which no fresh-water agency (unless we suppose narrow strips of lacustrine water capable of exerting a sufficient powei), could have scooped out. They ought not to be left out of consideration while speculating on the origin of high-level cwms.

South-west side of Llanberis Pass.—After passing Old Llanberis, the successive beds and rude terraces of felspathic lava, on the right hand, present a striking aspect. They lead up to the approximately level, though considerably rutted floor, of Cwm Glas. The headlands of this cwm on both sides are cliffed, so that while the sea was raging in the cwm, it was not idle on the more immediate declivity of Llanberis Pass. This declivity is indeed cliffed at various levels, and hollowed out into cwms. Between Cwm Glas and the lakes, there is the high-level cwm with a very sloping floor called Cwm Glas Bach, and above Llyn Peris one may observe a specimen of a not uncommon form of cwm with two outlets separated by an eminence or knoll.

Screes in Llanberis Pass.—The pass has chiefly derived its reputation for wildness from the heaps of débris which conceal the bases of the cliffs, especially on the north-east side. The Glyder Fawr would appear to have had a shivering fit ever since the excavation of the pass.

Stones varying in size from rock-masses fifty feet in length,* to the smallest fragments, lie scattered and piled up along its base.† They have fallen out of the mountain's side, in many places leaving turrets and pinnacles with which they must once have been in juxtaposition. A considerable number of the blocks must have found their way from recesses behind pillared walls of rock, the natural doorways of which look down from great heights towards the pass, as if to say to wayfarers, 'Ascend and enter, if you dare!' These recesses are perhaps the most sublime, as they are certainly the most secluded features of mountain scenery. Most of them have never been consecrated or desecrated (according to the light in which it may be viewed) by human foot, and some of them are probably beyond the daring adventures of the goat. Some distance below Pont-y-Gromlech, I saw a goat at a great altitude, with its fore-legs forming the upward continuation of a vertical precipice, and its head projecting beyond the perpendicular (Fig. 77).

Fig. 77.

In many places, in the Pass of Llanberis, the heaps of fallen blocks and fragments have obviously lessened the height of the cliffs, both by dilapidating their brinks and burying their lower parts. The narrow parts of the pass are in course of being filled up with the ruins of the Glyder Fawr. If the atmospheric theory of the origin of the passes be correct, why is the stream at the bottom of Llanberis Pass not carrying away the fallen blocks, instead of allowing its bed to be raised by

* Pennant says the largest stone in Llanberis Pass is 60 feet long.

† The majority of these stones may be regarded as having indirectly fallen from the cliffs—in other words, they may be glacial moraine débris.

them, and gurgling amongst them in continual danger of losing its identity? Was the stream larger at a former period? It is questionable whether the watershed of the pass could ever have supported a stream much larger than at present.

The culminating level of the pass is at a considerable elevation above the Llanberis Lakes, and about 1,000 feet above the level of the sea; but still it lies at a great depth beneath the tops of the immediately adjacent mountains. From the inn (in which tourists may obtain the best refreshments at very low charges), the eastern end of Nant Gwynant looks like an oblong bottomless pit, and the scenery altogether is unlike what any one could have expected. In a work of this kind, eggs, ham, and beer (which form the main subject of many works of home travel), are entirely out of place; but I may mention that whilst they were being prepared, I scrambled up the steep declivity on the left hand to see the lake-basin of Cwm Ffynnon, which can scarcely be called a basin, as it is very little depressed beneath the ridge which separates it from the pass. Behind it the bare and scraggy crags of the two rugged Glyders frown in solitary majesty.

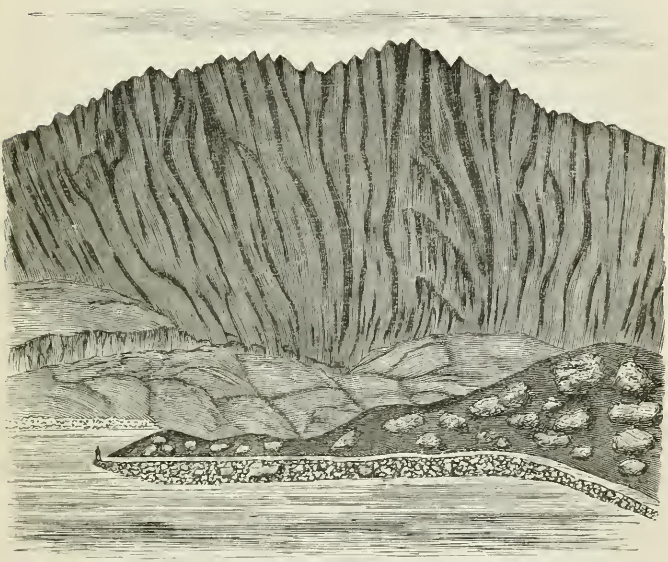
Successive Plateaux and Lake-basins.—I had not walked far along the miners' road, or Capel Curig route to Snowdon, before it became obvious that the great eastern declivity of the mountain has been scooped out into a great irregular valley, which ascends, not gradually, but by successive steps. Behind the lower and smaller Cwm Dyli on the side of Nant Gwynant, there is a steep escarpment with high cliffs at intervals. On the summit of this escarpment there is the large Cwm Dyli, with a comparatively level, and at intervals peaty floor. On the north side an eminence with a cliffed front separates it from the basin of Llyn Teyrn,* at a higher level. This basin has two outlets, through one of which the surplus water escapes. To explain it by any forward or downward process of excavation, would, I think, be very difficult. Its form seems to point to a process entering on one side, turning round, and making its exit on the other. At a considerably higher level than Cwm Dyli, you arrive at the glaciated plateau which forms the frontal barrier of Llyn Llydaw (1,800 feet above the sea), which on all sides excepting in front, is surrounded by high cliffs or slopes. Cwm Llydaw is one of the most impressive, though not one of the most regularly-formed cwms in Wales. On the north-west side the peaked and turretted ridge of Crib Goch rises to a great height, and, in certain states of the weather, seems almost to overhang the lake. But the 'dark and lofty' cliffs of Lliwedd, on the south-west side, are the most calculated to arrest attention. For at least half-a-mile in breadth and 700 feet in height (the summit is probably 1,000 feet above the level of the lake) they present a face of rock more approximately perpendicular, continuous, and sublimely furrowed than is perhaps to be met with in any part of Wales. (See Fig. 78.) The Lliwedd Cliffs are crossed obliquely by white veins of quartz. Their base is cleanly swept, with the exception of a few small deltas of screes. The sloping rock-surfaces under the cliffs have been more or less smoothed by glacial action.

The rock-basin in which Llyn Llydaw is situated has apparently been filled, at least in certain places, with

* On the side of the road from Pen-y-pass to Llyn Teyrn, and indeed all the way up to Snowdon, the rocks are rounded on the lee-side, and hollowed out in situations and in a manner that can only be explained by the action of the sea. The wave-marks are mixed up with and graduate into ice-planed surfaces.

drift containing rounded stones too large to be attributed to lacustrine attrition. It is probably of the same age with the marine drifts of other parts of Snowdonia. It may be well seen rising above the surface of the lake, and running beneath the water to a considerable depth, near to where the artificial embankment or miners' road crosses the narrowest part of

Fig. 78.



Dark and lofty cliffs of Lliwedd, or edge separating Cwm Llydaw from Cwm-y-llan—Llyn Llydaw in the foreground.

the lake. (See *Origin of Cwms, &c.*)* I think the surfaces of the frontal barriers of the lakes on the eastern face of Snowdon may be regarded as representing successive levels of marine denudation and deposition.

The Edge called Lliwedd.—This edge props up the

* Professor Ramsay regards it as moraine matter, and it may originally have been moraine matter left by the first great icy infillings of the Snowdonian valleys, as they retreated before the rising sea.

lower part of the peak of Snowdon, and runs along the south-west side of the great terraced valley I have partly described. Its north-east side is very precipitous, the cliffs above Llyn Llydaw reaching an angle between 70° and 80°. On the other, or Cwm-y-llan side, the edge slopes at angles varying from 45° downwards. There is apparently nothing in the petrological structure of this edge to account for the north-east side being so steeply scarped.

Glas Llyn.—On ascending the steep rocky escarpment which bounds Llyn Llydaw on the north-west, one of the finest, if not the finest scene in Wales, suddenly bursts on the view. It combines abruptness with magnificence of scale to an extent that leaves nothing to be desired. The crater-shaped basin of Glasllyn, with its bluish-purple waters (2,000 feet above the sea) is bounded in front by two ridges of glaciated hard felspathic rock, which slope down towards the narrow outlet of the lake. This outlet has apparently been filled up to a certain height by marine drift, with a grass-covered surface. This drift, I think, is distinct from the glacial débris, including *blocs perchés*, which may be traced to the south of the outlet. The ridge of Lliwedd forms the south side of the lake-basin. On the north, a steep slope, with tiers of rocky ledges and pillars, rises up to the serrated crest of the edge called Crib-y-dysgyll. In front of the spectator, or towards the west, the lake-basin is bounded by a steep cliff, above which the amphitheatrical form of the cwm is resumed, and continued with a gradually-rising floor all around, excepting on the Snowdon side, where the rocky cliffs rise up abruptly. To the south-west of the lake, the end of the Snowdon promontory rises almost out of the water, and towers to an overwhelming height. The spectator has to gaze so directly upwards, that the line of vision just misses the Ordnance pillar of stones on the summit, and along with it those artificial eyesores in the shape of refreshment sheds, which form so inappropriate a climax to a scene so wildly sublime and impressive. There are perhaps few other spots in Europe where one can look up from the farther borders of a lake to a height of nearly 1,500 feet * at an angle of vision amounting to about 50°. Above the minor precipice which directly bounds Glasllyn on the west, a small pool, marked on the Ordnance Map, formerly existed, but has been drained by mining operations.

The path winding along the northern side of the upper part of Glasllyn Cwm to its western brink is steep and rugged. The tourist has to cross several beds of temporary rain-torrents, by which the loose débris strewing the slope has been ploughed up and confusedly scattered. He cannot, however, fail to see that these torrent-beds bear no resemblance to either cwms or lake-basins, and that instead of *developing* the amphitheatrical form of Glasllyn Cwm, they are tending to destroy it. On reaching the summit of Y Wyddfa, or peak of Snowdon, and on reviewing the ground I had traversed, the impression seemed irresistible, that a powerful agency had not only eaten a deep and irregular valley out of the eastern side of Snowdon, but that the agency paused at successive levels, wore back previous slopes into cliffs, and left plateaux at different heights. It seemed equally obvious that neither the present brook nor any former representative could have given rise to a series of phenomena so mutually opposed in form as cwms, cliffs, and plateaux. What is the stream now doing in the upper part of its course—for instance, under Glasllyn? Merely rutting a continuous face of rock. What is it doing lower down? Alter-

* The height of the pillar of stones above Glasllyn is about 1,570 feet.

nately rutting transversely flat faces of rock, channelling marine drift, or finding its way through peat-bogs. What is it doing where all its force is concentrated, under the most favourable conditions for displaying its excavating power—on the steep slope of Lower Cwm Dyli, for instance? Making a maximum rut in ground which does not generally slope towards it, but presents a contour which bears no relation whatever to the channel of the brook.

VII.—FROM DOLGELLY TO THE PEAK OF CADER IDRIS.

From Dolgelly to near the second milestone on the old Towyn road, the ascent is gradual. The summit-level of the pass between Mynydd-y-Gader and the hill to the NW. is near a small and not very picturesque muddy lake, called Llyn Guernan. The road then leads through a longitudinal valley, which runs nearly parallel with Cader Idris, and which is quite open at the farther end, though its drainage, in the usual inexplicable fashion, escapes through an opening in the ridge which bounds it on the NW. In this valley you cross a number of brawling streams which run down the slope underlying the great escarpment of Cader Idris. At a distance of between three and four miles from Dolgelly, you commence the ascent of this slope, which is very rough work if you follow anything like a made path, for here, as elsewhere in Wales, the roads serve as the channels of temporary streams during heavy rains and the melting of snow.

About half-way between the Towyn road and the escarpment of Cader Idris, I saw a beautiful specimen of a smooth and rounded dome of rock; and near the summit of the part of the escarpment where the ascent is usually made, I noticed a large stone very distinctly striated. Its surface presented the usual appearance produced by the effects of weathering, namely, a minute roughness which covered every part of the glaciated surface, without interfering with the form of the ice-marks farther than by removing any polish which may previously have existed.

After reaching the summit of the narrow table-land of Cader Idris, about a mile and a half to the W. of the peak, I kept too much to the left for comfortable walking, but was amply repaid by encountering one of the wonders of Wales—the truly stupendous accumulation of large columnar stones which cover the slope of the headland called the Saddle, or Cyfrwy. Some one, whose time might have been better or worse occupied, is said to have counted 40,000 columns in the district of the Giant's Causeway, but here millions would probably not exhaust the number. They lie at all angles, and are piled on each other so as to thin-out in certain places, while in others they extend to an unknown depth. To what cause are we to attribute this vast array of prostrated columns? Here the theory of atmospheric disintegration would appear to be altogether out of the question. They occupy, more or less approximately, the site of a former bed of columns which stood closely side by side, and leaned towards the S., or at nearly right angles to the dip of the bed; so that no process of frittering away of softer intervening parts (as in the supposed case of Greywethers), will in any way explain their present arrangement. They retain their angles and their geometrical form. The cause of their being uprooted, dissevered, dispersed, and piled on each other, at first sight seems a mystery; and the difficulty of explaining them does not diminish when we come to examine more minutely their arrangement. In some places I noticed the very remarkable phenomenon of a circular hollow, with a column standing upright, or slightly leaning in its centre, as if a powerful eddy had once made these ribs of the 'everlasting hills' its sport. In other places the stones are arranged in terraces, rows, &c., and present other indications, not easily described, of the tumultuous action of water at different levels. The action of the waves and currents of the sea, laden with ice and icebergs, and probably enhanced by sudden upheavals or depressions of the ground, would alone seem adequate to account for all the features presented by this wonder of the principality.

Having passed the region of columnar stones, I saw the outcrop of one of the beds of slate marked in the section (Fig. 30, p. 150), indicated by loose splinters on the surface; and soon after commenced the ascent of the peak, which rises between 300 and 400 feet above the depression on its western side. The headland of the Saddle was left behind, and the gable-end of the ridge called Pen Coed, which overhangs Llyn Cae, or Cau, came into view. The side of the peak consists of a number of rocky projections (greenstone, felspathic trap, &c.), among which it is much safer to clamber than to take the beaten path near the brink of the precipice on the left. About two-thirds of the way up the peak, the pedestrian, if he be not accustomed to such situations, is liable to become frightened as he finds himself on a narrow isthmus between two semicircular abysses, into which, after walking a few yards to the right and left, he can see as far down as the waters of Llyn Cae and Llyn-y-Gader—the first about 1,250 feet, and the second about 1,050 feet beneath the spot on which he stands. On reaching the sharp apex, he may find a relief by leaning against the Ordnance Survey pillar of stones. Should he stand in need of no such assistance, he ought to be cautioned against venturing too far down the steep slope on the left, or he may very soon find himself on the suddenly commencing brink of a nearly perpendicular precipice * at least 700 feet in height, the base of which graduates into the sloping ground above Llyn-y-Gader. It was over this precipice that Mr. Smith, a tailor, of Newport (Monmouthshire), would appear to have fallen in the autumn of 1864. His body was found near the shore of Llyn-y-Gader the following spring. The cwm or amphitheatrical basin of Llyn-y-Gader has been scooped out so as to cut away nearly half of the conical peak of Cader Idris. Hence the possibility of the tourist finding himself, when too late, on the sharp edge of the unexpected precipice just mentioned.

It is not very dangerous to descend from the apex in the direction of Llyn Cae, and the eastern declivity of the peak is not steeper than the western ; but the line of cliffs on the north side of the comparatively level table-land to the east of the peak must be carefully avoided. In one place the table-land curves down a little towards the brink of the cliffs. I have been informed, on good authority, that an incautious tourist who had ascended from Tal-y-llyn, was seen walking right across the narrow table-land until he had reached the commencement of the curving down towards the brink of the nearly perpendicular cliffs. A few feet farther and the inertia of his body must have precipitated him to a depth of not less than 1,000 feet. He was fortunately seized by two or three experienced mountaineers who happened to be close at hand.

The Tal-y-llyn side of Cader Idris is very rocky, and the forms of some of the rocks very varied and singular ; but the long continuous range of cliffs on the north side forms the most remarkable feature of the mountain,

* At an angle of about 80°. (See *Origin of Cwms.*)

next perhaps to the juxtaposition within a few hundred yards of two lake-basins separated by a narrow-peaked ridge which rises above them to a height of from 1,050 to 1,250 feet.

VIII.—FROM RHAYADR TO CEFN COCH, NANT GWYLLT.

The basins, cwms, and some of the gorges, in the neighbourhood of Rhayadr, have already been noticed under different heads. The town itself presents few attractions. But its inhabitants are much more intelligent than we generally find in an English town of the same rank. Mr. Stephen Williams, railway surveyor, is a very well-informed local geologist. He assured me that the valley of the Elan, the narrowest part of which is called Cefn Coch, was, in some respects, better worth visiting than the Pass of Llanberis.

The road lay over an eminence covered with an immense accumulation of drift, which Mr. Williams (if I remember rightly) believed must have come out of Gwyn Llyn Cwm. It soon became evident that the River Elan could not have deposited this drift, for it might be seen running up the face of the slope on the right hand with a smooth continuous surface, while the river was only encroaching on its lower border, and producing nothing like it in its channel farther on. The road continued along the NW. or right-hand side of the valley, which was well wooded. At a considerable height above, a series of six terraces presented a very singular appearance. In front the rocky precipices of Cefn Coch gorge gradually assumed a wilder and more rugged aspect. Arrived at the commencement of the gorge, the scene seemed to baffle all description. On each side of the road was a grassy, alluvial (?) flat, strewn with stray fragments from the cliffs on the right. The river on the left was of very considerable breadth, and its bed was not only paved with stones, but enormous blocks, at short intervals, rose above its rippling and foaming waters. I have not seen any other wide river making its way through and over so many large blocks of rock. In the middle of the gorge, which may be about a mile in length, the stones lay scattered in every direction. It would be going too far to assert that all of them have fallen from the adjacent cliffs since the last rise of the land above the sea; but many of them probably, and some of them certainly, are recently-fallen blocks. I saw blocks as large as a Welsh cottage, or at least twenty feet in average diameter, and found perfect shelter from the wind on the lee-side of one of them. The cliffs on the left-hand side of the river are very fine, but I have seen nothing to surpass those on the right. From the scree-strewn or rather block-strewn base to their grass-covered brink, the height cannot be less than 800 feet. In many places they are mural and quite perpendicular.

I left two friends under the protection of the large stone already mentioned, and proceeded towards the farther end of the pass. At a little distance, I unexpectedly saw something like a house, and concluded it must be an uninhabited shed. On drawing nearer, the monotonous sound of many voices revealed the fact that this 'solitary place' was gladdened by the presence of a school. The mistress, who was a native of Dorsetshire, explained why a school came to exist in such an unlikely situation. It was nearly equidistant from the green valley-expansions on both sides of the uninhabitable gorge. On inquiring whether danger might not be apprehended from the crags, some of which literally overhung their bases above the school-house, the mistress pointed to an immense stone, lying only a few yards off, which had fallen with a thundering noise several years before ; and stated that the building was about being removed (as I understood her), to a safer situation under a rake or gulley in the cliffs which was supposed to have become exhausted, or to have reached the angle of repose. But I do not think the school-house will ever be out of danger in any part of this cliff-bounded pass ; and the fall of a block twenty feet in diameter would at any time be almost sufficient to erase the building from its site, and throw its shattered ruins into the river, to say nothing of the possible fate of its innocent daily occupants.

The situation of this school-house arises from a geological cause. As already stated, an inhabited valley-expansion exists at both ends of a sterile rocky gorge. By what agency was the gorge excavated, and what gave rise to the valley-expansions? (See *Longitudinal Valleys and Transverse Gorges.*)

The River Elan, when I saw it, did not appear to be doing much in the way of denudation. But during floods, its power must be considerable. I had not time to visit the upper part of its course, but the Rector of Rhayadr assured me that there the scenery was most glorious. In winter, when a thaw is commencing, the ice assists the river in carrying nearly all before it. The ice not only enables the river to remove stones, but to strip the bark and even the branches off trees. It must be confessed that even in our own country we are still very ignorant of the power of rivers in the upper or more inclined parts of their channels, during floods arising from heavy rains or sudden changes of temperature.

The tourist, if he can walk as far, cannot do better than reach the upper part of the valley of the Elan, by way of Gwyn Llyn from Rhayadr—then descend its channel to Nant Gwyllt, and return through the gorge of Cefn Coch, or *vice versâ*. The old road from Rhayadr to Aberystwyth passes through or near to a number of scenes of the most rugged desolation, in the shape of gorges half buried in ruins.

IX.—AROUND BUILTH—ABEREDDW CLIFFS.

BUILTH stands on two terraces of drift rising on the south side of the River Wye. It is surrounded by what may be called an irregular longitudinal valley, of which the long gorge of the Wye, extending to Three Cocks Junction, is the outlet. To the north, on the other side of the river, are well-known bosses of trap. The circumstance of their having held up their heads so long while the aqueous rocks around them were being wasted away, does not accord very well with the subaërial theory, for the substances of which they consist are the most liable to be affected by the chemical action of rain. Neither would these igneous rocks seem to be more easily eroded by fluviatile action, for in them the river has had ‘a tough morsel to grind’ at the spot above Builth, commonly called the gorge of the Wye.

A walk from Builth to the summit of the eastern part of Mynydd Epynt will repay the tourist. About a mile and a half from the town, he will suddenly come in sight of a picturesque wooden bridge, at the lower end of a very narrow rocky gorge, through which a brook runs at a rapid rate. This is a specimen of what may be called the *inlet* in contradistinction to the outlet gorge of a valley-expansion. On retracing his steps for a short distance, crossing the brook by a bridge lower down, and commencing the ascent of the hill by the nearest route, he will see on his left one of the finest cwms in Wales, embracing nearly three-fourths of a circle. It has obviously been hollowed out of a previously-existing acclivity, and is not a mere variation of the original contour of the mountain. Before reaching the summit, he will begin to hear the gentle tinkling sound of a brook, not descending towards the cwm, but into a gorge on the right hand, by a series of waterslides. There is something very sublime in the Huttonian doctrine, that to such brooks, in co-operation with rivers, is consigned the mighty task of carrying whole mountains to the sea. But even in a region where brooks and rains might be regarded as the lawful claimants of the whole domain of denudation, there are formidable difficulties in the way of referring the phenomena exclusively to the action of these agents.

In course of time, the by-path the tourist is pursuing will bring him back to the main Brecon road, which he left a short distance below the wooden bridge. On deviating in a westerly direction towards the main ridge of Mynydd Epynt, he will gradually come in sight of the south-eastern side of the great table-land of Central Wales, which has been gored down by some fell gulley-making process, fluviatile or marine. This table-land has sometimes been called the 'Land of the Gorges,' from the number of deep ravines by which it is indented.

The Land of the Gorges will require several days for its exploration. On ascending the steep side of one ravine, the pedestrian will find himself on the verge of another. Here there would seem to have been a fell confederacy of fresh-water streams, each bent on rivalling the achievements of the sea in reducing table-lands to a series of radiating wrecks. But, as if to evince the universality of its dominion, the sea, from time to time, has taken possession of these ravines, and modified their contour; for on no other hypothesis can all the phenomena they present be satisfactorily explained. Here the denudation would appear to have been of the same mixed and alternating kind as that indicated by the Longmynd 'gulleys.' (See *Around Church Stretton and up the Longmynd Gulleys.*) The ravines run approximately parallel, and nearly in a southerly direction. In one of them (near Capel-Ystrad-ffin) the River Towy makes at least half-a-dozen grand leaps, not mere hops, in its descent from near the summit of the table-land to the more habitable part of the country. In course of time, as it lowers its channel, it will probably leave off its sportive or waterfall mode of excavation, and have recourse to a more steady method of grinding down its bed till it reaches a depth, like that already attained by some of its neighbour streams, quite appalling to behold from the adjacent heights.

Abereddw Cliffs.—These cliffs, about five miles SE. of Builth, are the most attractive objects in the more immediate neighbourhood of the town. I visited them in company with two of the members of the Builth Geological Society. They consist of Ludlow rocks of varying compactness, the hardest often forming their base. They run along the side of the valley of the Wye for at least half a mile. There are four principal lines of cliff, with several subordinate ones; the latter apparently worn back, at intervals, so as to merge into the principal. At their northern termination they are separated from a lofty single cliff-line by a dry inlet, the sides of which consist of cliffs of much the same form as those facing the valley. The existence of this inlet, the floor of which rises up obliquely to the planes of stratification, is, at the very outset, a fatal objection to the theory that the cliffs have been formed by rain and frost, and it is equally inexplicable by river-action. On the north side of this inlet, there are several pillars which present a smoothed outline easily distinguishable from any shape produced by weathering. Beyond the upper termination of this inlet, the left-hand line of cliff is continued, and here and there its base exhibits small caves, beautifully smoothed and rounded in a way that fresh-water streams (supposing them once to have been here), could never have accomplished. At the base of the lowest of the main lines of cliff, and at perhaps fifty feet above the railway, there are several caves with arched entrances. In one cave two lateral openings communicate with the main entrance, and on one side of the latter, a pier only a few inches in diameter supports the superincumbent fabric. The interior of the cave is here and there rounded and smoothed.

Fig. 79.

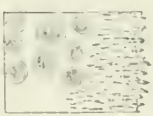


Fig. 80.

In many places the Abereddw cliffs show few or no signs of weathering, but in most places weathering has proceeded to a very considerable extent. Its effect, however, is to ruin the cliffs, and most assuredly not to *form* them. It is precisely undoing what the sea has effected. The line of demarcation between the rough faces of rock, from which chips or splinters have been detached by weathering, and the smooth and regularly-sculptured faces left by the sea and preserved in sheltered situations, is often clearly defined. (See Fig. 79.)

On the broad level platforms at the bases of the lines of cliff, there are here and there a few large blocks of rock. But they chiefly occupy positions where they could not have fallen, and to which they must have been carried. The platforms vary in breadth from 150 down to a few yards, and are generally covered with silt or loam. The third platform, reckoning upwards, inclines about 3° transversely, and 5° longitudinally. In several places a line of cliff turns round at nearly right angles, similar to what may be observed on modern sea-coasts; and beyond the abrupt corners, the rocks are often the most smoothed and rounded. No agent merely *passing by* could have given rise to such phenomena. But they are such as the face-to-face action of the sea produces on lines of cliff irrespectively of their sudden change of direction.

In many places the faces of the cliffs exhibit smooth curvilinear grooves, and finely-graduated shallow pits, which have apparently been formed independently of any corresponding variation in the structure of the rock. The grooves might easily be explained by glacial action, were it not that they are slightly inclined (along with the line of cliff) up the valley, or towards the direction from which the glacier must have come, and that they follow the windings of the cliffs so as often to make their appearance on the *lee*-side. Neither can the pits be explained by glacial action, but fac-similes of both pits and grooves may be seen on sea-coasts at the present day. It is, however, possible, if not probable, that coast-ice may have assisted the sea in sculpturing the Abereddw cliffs.

Between the Abereddw cliffs and Builth, the railway-cuttings furnish several good sections of drift. It is worthy of notice that where the sides of the valley are lined with drift, rounded stones of various sizes may be seen in the channel of the river. It is equally remarkable that where the bare rocks, or rocks only covered with angular detritus, come down to the river-channel, very few rounded stones, and scarcely any large rounded boulders, are to be seen in the latter. But this is not the only fact which points to the conclusion that the river-drifts of the Wye are principally a redistribution of previously-existing drifts, and that the latter were not deposited by river-action. In the neighbourhood of Newbridge Station, between Builth and Rhayadr, large stones are to be found congregated in one place, and small stones in another, in a manner that river-action will not explain. (See Fig. 80.) In other parts of the valley of the Wye, the occurrence of boulders in groups, as if they had been dropped by floating ice, is a common phenomenon.

X.—FROM EXETER TO BUDLEIGH SALTERTON—AUTOBIOGRAPHY OF A PEBBLE.

The whole of the neighbourhood of Exeter shows striking indications of marine denudation, or at least of the sea having been over the land up to a certain height at a comparatively late period in the geological history of the world. The occurrence of lithodomous perforations in the neighbourhood of Torquay * up to a height of between 200 and 300 feet above the sea-level, renders it almost certain that the great plain through the southern part of which the River Exe flows, and one side of which is traversed by the Culm, was once an inland sea, while the narrow valley to the W. of Exeter, was a sea-strait. If the gravels (consisting of flints, carboniferous or carbonaceous (?) grit pebbles, &c.) of this area, were not then first distributed, they must have been rearranged by the sea. On walking from Exeter to Exmouth, the grit pebbles in the gravels

* See *Preservation of Lithodomous Perforations.*

which line the eastern side of the estuary of the Exe, become gradually replaced by redeposited new red sandstone pebbles mixed with flints. On the coast between Exmouth and Budleigh Salterton, nearly the whole surface is covered to a greater or less depth by this gravel. But it is very difficult sometimes to distinguish between triassic pebbles *in situ*, and the same in a reassorted form, unless where the presence of chalk flints furnishes an evidence of redistribution. Everywhere about Budleigh Salterton the mixed flint and pebble accumulations are interwoven with finely-laminated and often false-bedded sand, or sand in the shape of lenticular patches. On the sea-coast, near the town, the stony gravel is interstratified with distinctly laminated sand, and extends to a depth of at least twelve feet. The sand is sometimes as solid as the rock below, and no difference as regards the form of lamination can be detected between the two. But this is not the only indication of the marine origin of the gravel. Its occurrence on ridges, as well as in valleys, is a proof that it cannot be of fluviatile origin. Indeed, the river here, as elsewhere, has only been instrumental in removing and redepositing portions of the marine-gravel. At this, and no other conclusion, can any one arrive who has spent much time in examining the mode of occurrence, positions, internal arrangement, and composition of the gravels of the valleys of the Otter and Axe.

On the sea-coast to the W. of Budleigh Salterton, Mr. Vicary, F.G.S., of Exeter (a very sound and trustworthy local geologist), has collected many pebbles which, on being broken, are found to contain the well-preserved remains of shells and crustacea. The latter have been classified, described, and figured by Mr. Salter, F.G.S. ('Quart. Journ. Geol. Soc.' for April 1864); and they disclose the marvellous fact that the pebbles containing them must have been derived from a Lower Silurian sandstone equivalent to that now found *in situ* in Normandy. The pebble bed, which on the coast may be seen dipping towards the E., crops out on the surface of a ridge which extends many miles inland in a northerly direction. Pebbles during one or more of the later submergences of the land, must have been washed out of this ridge, and mixed with flints derived either directly or indirectly from a former covering of chalk. In this superficial gravel may be found pebbles similar to the one which is here supposed to relate its history before the members of the Exeter Literary Society :—

Autobiography of a Pebble.

Ladies and Gentlemen,—Though only a plain Devonshire pebble, with nothing to attract the vulgar eye, I conceive I have a right to relate my history; for, in addition to what one of your poets has said about there being 'sermons in stones,' I find that many of my brother pebbles strew your promenades, decorate your gardens, and even form a covering for your graves. What I have to tell you is not mere romance, but lies as much within the province of truth as the fact that other pebbles, in different parts of the globe, above or below the sea-level, are now passing through the phases of a career similar to my own.

I forbear saying anything about my remote parentage, being about as ignorant as yourselves of the first origin of the grains of sand of which I am principally composed. Indeed, my recollection only carries me back to a time when the particles of a great arenaceous formation were being quietly deposited in a moderately deep sea which covered the area now called Normandy.

The sand gradually became hardened into stone, which afterwards slowly rose above the sea till it formed a mountain of no mean altitude. I was then at the culminating point of my oscillating career, for I formed a part of the surface of a stratum of sandstone on the very summit of the ridge; and the quartz crystals, which I still retain, then glistened resplendently in the rays of the primeval sun. But a dark day dawned—I have seen nothing like it since—a thunderstorm enshrouded my native mountain home, and a flash of lightning fractured the old block of which I am only a chip—sending one-half hurling down the south-western, and the other down the north-eastern declivity. Where my twin-fragment went to, I could never learn; but were any one to assert that it now forms part of a gravel bed in Ireland, it would be difficult to bring forward any satisfactory proof to the contrary. As for the fragment constituting my former self, it bounded along the slope with frightful rapidity, until it fell into a brook with a splash; but I have ever since been thankful that my fall did not prove the destruction of any living creature—for though my heart is stone, I have seen enough to teach me a lesson of universal benevolence. By the brook I was conveyed to a river, and by the river to the sea. But I have been so many times under salt water, that I must enumerate as I proceed, and shall call this submersion No. 2. Near the delta of the river I reposed for centuries by the side of the decaying trunk of an old tree. By-and-bye, an unfeeling current came and swept my woody companion away, and I have reason to believe that the same was lately found petrified in a coal mine in South Wales. This event happened about the middle of the Carboniferous period, but I am ignorant of all the changes the tree underwent before it became replaced by stone. As for myself, I was destined not to remain much longer under water, for an earthquake upheaved the bed of the sea, so as to convert the shingle of which I formed part into what some of you would call a raised beach. During a long and dreary lapse of time, I remained a pebble in this beach, which at one time stood high, at another low, but never sunk entirely under water until the arrival of the most important event in my history afterwards to be noticed. I patiently endured the period of extreme cold when, in several neighbouring districts, the angular fragments of your so-called Permian breccia were accumulated by ice,* but fortunately escaped being fractured by the frost. At length the new red sandstone era dawned. The sea encroached as far as the raised beach, and began to wash away the ready-made pebbles, and to make fresh pebbles out of the Silurian sandstone rock beneath. During a storm I was hurried away among the rest, and became imbedded in a newly-formed beach, where I found myself mixed up indiscriminately with Devonian slate and limestone, greywackè, lydian stone, schorl, trap, white quartz, sandstone, &c. My own name is quartzite—that is, decomposed, redeposited, and consolidated quartz, with a little, and only a little, admixture of foreign matter. This was during submersion No. 3. The beach was formed, removed, and renewed at least a thousand times, until through rubbing, rolling, rattling, jostling, tumbling, rising, falling, advancing, and receding, with my fellow pebbles, I became reduced in size, so as to approach my present dimensions. For many ages we all travelled in company, along the many

* Professor Ramsay, and others, believe that the angular breccias of the Permian period were not a sea-shore deposit, but were accumulated by glacial action. To this opinion Sir R. I. Murchison demurs in the 4th ed. of *Siluria*, p. 498.

windings of a sea-coast, until we became stationed at an almost incredible distance from our place of starting.* At last we became imprisoned under a thick bed of ochreous sand, beneath which we rested secure for centuries. Then came another upheaving process, which, however, did not very much disturb the horizontality of the great formation of which I formed a part. I will not tax your patience with a statement of the number of times this formation oscillated up and down; neither will I dwell on the manner in which, during my next submersion, No. 4, liassic lime and mud accumulated over the sandstone, or explain how the slightly-upturned edges of the sandstone and lias were partly washed away; how the greensand overlapped both these formations, and was itself buried under a thick crust of chalk; how the chalk was dissolved away, leaving heaps of flints; how the latter became blunted and rounded, and mixed up with new red conglomerate pebbles, detached from the parent rock at the bottom of the sea. I must be content with stating that I was one of the fortunate, or unfortunate (as may prove to be the case) pebbles which became disinterred, and that I had to undergo another process of rounding and reduction in size (I hope it will be the last); after which the land rose above the sea, and I found myself by the side of uncouth-shaped flints and hard blocks of chert, in a gravel bed between the places now called Budleigh and Exmouth. The story of my submersions is not yet concluded. The fifth time I sunk beneath the sea was during the period when the limestone rocks of East Devon were lithodomized. The upper part of the Budleigh and Exmouth gravel bed was then scattered and

* It is believed that limestone pebbles found in the Chesil Bank, near Portland, must have travelled all the way from the coast near Torquay.

rearranged, but I lay sufficiently deep to be out of the way of any further jostling to and fro. This was *positively* the last time I was under the sea, though I narrowly escaped a sixth submergence at the period when the *Scrobicularia*-mud of the valleys of the south of England was deposited over the ruins of sunken forests.* During the latter part of the time I slumbered in my last resting-place, man became a denizen of the earth, and spear-heads and knives were made out of flints at no great distance from where I lay.† Elephants, bears, hyænas, and other animals now strange to your country, more than once trod over my head. Primordial races of men imitated my old acquaintance, the Ichthyosauri, in eating each other. At last humanity became civilised. Monarchs were born, reigned, and died, while I continued to slumber in my pebble-bed. Empires rose and fell. Cities flourished and were laid in ruins. Battles were fought, lost, and won. But the so-called pomp, splendour, and glory of these events appeared to me truly insignificant when compared with the rise and fall of mountains, the growth and decay of continents. The period they embraced now seems to me like a small pale cloud on the horizon of time!

But to resume my history. The other day I was detached from my gravel bed by a cruel geologist, in whose hand I am now exposed to the gaze—I fear the disrespectful gaze—of the offspring of Adam, whom I can scarcely help regarding as a creature of yesterday. Consign me to my parent earth, and I shall be content; but I have humbly to request that I may not be exposed, like a monkey, on the shelves of a museum—especially

* The extent of this submergence in different parts of the south of England is yet far from being known.

† They have been found in Kent's Cavern, near Torquay.

of a museum where specimens run a chance of receiving wrong names; for fancy my surprise, if one morning I were to find myself labelled a 'rolled coprolite.' Neither should I consider myself flattered if I were to be called a 'Budleigh popple.'* How long I shall continue to exist I cannot tell, but I have no wish to go through the tear and wear of another eternity, for that has been long enough I have already endured. Ye sons of men, take a lesson from me, and learn that were ye to live as long as I have existed, ye would still be mortal, and hence learn to prepare for an unchangeable state of being.

XI.—FROM ASHBY-DE-LA-ZOUCH TO CHARNWOOD FOREST.

FROM the high grounds near Coleorton, to the E. of Ashby-de-la-Zouch, the SW. or main porphyritic ridge of Charnwood Forest presents a rather striking aspect. The forest area is here seen rising above and apparently out of an extensive plain of new red sandstone. With the exception of the cultivated parts, it forms a very unexpected break in the general character of the scenery of the midland counties. It is wildness located in the midst of tame luxuriance—desolation intruded into a region of busy social intercourse—solitary sublimity enthroned within sight of human habitations, and within hearing of the hum of industry and the voice of revelry. It looks like a part of Wales cut off and planted in the midst of 'merry England'—an outlier of the great mountain territory of the principality. In the slate and porphyritic region of Charnwood Forest the geologist really recognises a part of Wales continued under the intervening new red, Permian, and carboniferous strata, and here uplifted to view.

* The local name given to pebbles in the neighbourhood of Budleigh.

Though the best view of the wildest part of the forest may be obtained from near Coleorton, the easiest way of reaching it is by taking the train to Coalville Station. Before making for the forest, the tourist would do well to visit the Whitwick collieries. Near the colliery-office he may see specimens of greenstone graduating into what looks like compact basalt, being portions of a sheet of trap which, in this district, rests on the coal-measures. It is supposed by some to have flowed from the adjacent eruptive vent of Bardon Hill; but a local geologist has attempted to trace its derivation to a vent indicated by an exposure of greenstone a short distance to the SE. of Whitwick village. In two of the Whitwick coal-shafts the bed of greenstone is 63 feet thick. In one of the neighbouring Snibston pits its thickness is 21 feet. It was first shafted through under the direction of Mr. George Stephenson, at a time when it was regarded as an underground extension of the forest rock—called granite by the miners—through which no human agency could penetrate. Mr. Stephenson would appear to have been fully aware of the locally intrusive nature of igneous rocks. He descended the shaft, and after examining the trap he said: 'I looked the fellow round about; I saw he was a stranger, and had no business there; so I thought I would have a good rattle at him.'*

From Coalville the tourist can easily find his way to Forest Gate and the Reformatory. Between these two places, by deviating from the main road to the right and left, he can see many fine exposures of the slate and porphyritic rocks, though the most striking porphyritic boss is High Cademan, about a mile above Whitwick village.

* I had this anecdote from one of Mr. Stephenson's mining agents, at Clay Cross, in 1847, and communicated it to a late number of the *Geol. Mag.*

At the Hanging Stones, in the interior of the forest, the rock has the appearance of a breccia passing into porphyry. There is a pillar about 20 feet high, which has evidently been left by the removal of the once-contiguous blocks. Many blocks may be seen in the neighbourhood in positions where they could not have fallen. Some of them might be brought back, and almost fitted into the vacancies they apparently once occupied. The pillar exhibits fractures, the sides of which are as fresh-looking as if they had originated yesterday. The weather here seems to have literally no power. The shape of Greenhill Tor is likewise due to the fragmentary displacement, not the granular dissolution of once adjacent rocks. The rocks and cliffs of Timberwood Hill, near Green Hill, form an extension of one of several irregular lines of cliff I succeeded in tracing between Mr. Green's house and the Reformatory. The neighbourhood of Timberwood Hill is strewn in some places to a great depth with loose fragments and blocks, in such a manner as to suggest a powerful transporting agency.

The porphyritic and slate districts of Charnwood Forest are the wildest, but the syenitic knolls (now believed by Dr. Holl to be of Laurentian age) and the trap ejections afford a pleasing variety. It would be difficult to say how far some of the latter are hills of denudation or elevation; how far they were once buried under newer stratified deposits which have been stripped off by denudation; or how far they held their heads above the level of sedimentary deposition. A survey of Charnwood Forest suggests a number of other questions which have not yet been satisfactorily answered—such as the age of the slates and porphyries relatively to the syenites and traps, the origin of the porphyries, whether metamorphic or eruptive, or both, &c.

On the side of the footpath leading from the Reformatory road towards Green Hill, I noticed a block of porphyry enclosing a fragment of fine slate, with the boundary line between the two very sharply defined. Other instances have been discovered; and how far such included fragments throw light on the mode of formation of the porphyry is an important inquiry in the present state of geological speculation.

The internal structure of Charnwood Forest has received a very unusual share of attention. For information on this subject the tourist cannot do better than consult several articles in the 'Geological Magazine.'

XII.—A WALK OVER MALVERN WYCH—A MIDNIGHT WAKING DREAM OF THE LAPSE OF TIME.

THE moon in its last quarter had just appeared above the summit ridge of the Malverns, casting deep shadows into the 'dismal hollows' around. The ground between Colwall and the commencement of the ascent looked like the stagnated undulations of a great primeval earthquake. The crust of the earth has here indeed been tossed to and fro, its strata pitched over, and its lowest foundations upheaved into a mountain range; but the heights and hollows which now appear so strongly contrasted are the monuments of a denudation which, compared with the date of these convulsions, happened only yesterday. The road begins to ascend. An immense mass of débris, whitened by the moonbeams, marks the exit of the railway tunnel, and emphatically suggests the idea of a rifled sepulchre of myriads of trilobites which, in their day, were the lords of creation. But the day † of these acute-sighted crustaceans

* A name applied by Camden to the cwms of the Malvern Hills.

† The trilobites at this spot are found in Woolhope Limestone.

becomes comparatively modern, when viewed through the vista of the long series of ages which have transpired since the foundation-stones of the mountain mass beyond were tranquilly laid down at the bottom of the sea.

The ascent suddenly becomes steeper. The artificial pass called the Wych is reached. The traveller, at midnight, is now on the summit of a ridge, the history of whose formation, uprisings, downfallings, submersions in water and in fire, would form a romance more marvellous than any which has been conjured up in the mind of a sensational novelist: a romance not so much of quickly-following catastrophes, as of the slow agency of water and fire during long and dreary lapses of duration, with intervals of paroxysmal violence. Grain after grain of the felspar, hornblende, and mica of the rocks, around and beneath, must have been quietly deposited on the floor of the Lower Cambrian (?) sea.* How many great geological events have since then taken place? How often has the huge mass of primeval strata been upheaved or depressed, and subjected to the action of fire, hot water, or steam? How many upstartings along with, or protrusions through, the secondary crust of the earth, has the ridge of rocks on which we stand experienced? How often has it served as a sea-coast, since the worms whose traces have been preserved at a lower level † burrowed in the sands of Upper Cambrian shores? How much of the original bulk of this now narrow ridge has been swept away by waves, washed down by rains, or splintered by the bolts of heaven? Has it been covered once, twice, or thrice by glaciers? Have icebergs stranded on the

* According to Sir R. I. Murchison (*Siluria*, 4th ed.) the rocks forming the nucleus of the Malverns are of Cambrian age—according to Dr. Holl, Laurentian.

† In the Hollybush Sandstones.

Malvern Hills, or have these hills been ground down and smoothed by the ponderous march of a whole continent of land-ice? What power has hollowed out their cwm-shaped abysses, scooped out their abrupt valleys, and rounded their peaks? Some of these questions perhaps can now be answered; some cannot yet be answered; some may never be answered. But, to the question, How long is it since the first of the above series of events occurred? the answer must be, 'A lapse of time wholly immeasurable.'

On contemplating the structure of existing mountains the mind is irresistibly led backwards to the era of a former world, but in that world it recognises a mass of ruins. It penetrates still farther through the mists of antiquity, and another world rises before it; but in that world it still sees the wrecks of antecedent continents, and nothing as yet appears whence a ray of hope may beam on the bewildered imagination—of hope that it is approaching the period of a beginning. Worlds precede worlds in 'dim array,' and the remotest boundary of the awful horizon exhibits no symptoms of the primeval verge of time. Yet no one need be afraid of such reflections tending to destroy the distinction between time and eternity, as that distinction must remain the same whether a century or an incalculable period be assigned to the world. The whole age of the earth, with its unnumbered cycles, is, after all, but as a grain of sand in the desert of infinite duration.

The Wych is passed, and the abrupt eastern descent of the mountain commences. On the left hand, valley after valley is revealed by the dim nocturnal lights and shadows. Their origin is more or less involved in mystery, whether their forms are contemplated by night or by day.* The road soon crosses the lower end of a

* See Chapters viii. and xiv. Part iv. Book II.

valley in which a lady some years ago erected a summer-house, which was destroyed by lightning. Mr. Ballard, of Colwall (an able surface geologist), informed me that he had more than once seen the rocky projections of the Malvern Hills shattered by lightning. It is a subaërial, or rather aërial agency, which ought not altogether to be lost sight of while endeavouring to account for the loose stones which may be seen strewn under cliffs. The end of the deep and gloomy gorge which opens on the road near Lady Huntingdon's Chapel is passed, and the centre of Great Malvern is reached at a time when there is not a whisper to disturb the musings of the contemplative geologist.

XIII.—AROUND BEWDLEY.

The scenery of the neighbourhood of Bewdley, in Worcestershire, is more beautiful than magnificent. It furnishes, however, some very unmistakable illustrations of the action of the Severn Sea, especially during its declining days, on easily denuded triassic sandstone. From near the railway station, on looking south, one may see a picturesque discontinuous escarpment, cliffed at intervals, and cutting across the country irrespectively of the shape of the ground on which it has been imposed.* As at the present day on sea-coasts, the highest grounds have here been the most steeply scarped. To the north of this escarpment, a large area is covered with extra-rounded shingle and sand, which on steep slopes generally gives place to angular drift. A section of this angular drift is exposed to the south of the railway station. The fragments fill up a depression in the solid

* It extends from the gorge of the Severn at Blackstone Rock, along by Mount Pleasant, to the east of the railway tunnel. It is crowned with trees.

rock, in a way clearly indicating that they have been transported to, and not merely left in, their present positions.

One day I went out with Mr. Gabb, the local geologist, to visit the Devil's Spittleful. On the way he called my attention to the fact that at least nine-tenths of the pebbles strewing the surface of the ground presented somewhat the shape of a fossilized bivalve shell, very much rolled. It might be worth while to inquire how far this peculiarity of form may be indicative of the mode of rolling, or of the nature and direction of the agency by which the pebbles were rolled. It would appear to have something to do with composition, for while the pebbles of the above form are very nearly all sandstone passing into quartz rock, the white quartz pebbles are quite distinct in shape.

The Devil's Spittleful, a short distance east of Bewdley, is a boss of sandstone rock, with very steep sides, which rises all at once out of the lowest part of a depression. This depression is more or less swampy, and in wet weather the boss of rock is nearly surrounded by water. It would be interesting to make observations with the view of determining whether we have here a rock-basin, or merely a hollow with a barrier of drift. If a rock-basin (and I suspect it is), a glacier would scarcely explain its excavation, as the central projecting rock presents no resemblance to even the most abrupt *roche moutonné*.

Habberley Valley, north-east of Bewdley, is very celebrated for the beauty and variety of its scenery. It is a large irregular cwm, with a narrow entrance. As you approach it, a series of beautifully-rounded small cwms may be seen on the right-hand declivity. The great area is divided into smaller depressions, with connecting passages, and intervening smooth ridges and knolls. At intervals there are cliffs with stratification, both conformable and inclined to the level ground at their base. I noticed one cliff in particular which must have been denuded obliquely to the stratification in a way alone explicable by the action of sea-breakers or currents. A picturesque sandstone projection, called Pecket's Rock, rises up on one side of the valley, to the base of which the level and cleanly-swept ground comes up, excepting at one spot where there is a talus. The valley is closed behind by an imposing wall of rock. While here and there we perceive indications of sea-coast action, the generally smoothed and rounded form of the depression would seem to point to the eddying and scouring agency of oceanic currents.

Some distance to the north of Bewdley, on the eastern side of the Severn, may be seen a number of small basins, locally called the Tubs. They have been hollowed out by tiny cascades in the channel of a brook.

XIV.—FROM WOLVERHAMPTON TO AN ICEFLOE-CARGO* OF BOULDERS.

THE scenery of the Black Country is not generally regarded as very picturesque, but it is very interesting in connection with the later changes of the earth's surface. The Silurian anticlinal ridge extending from Dudley to the neighbourhood of Wolverhampton shows the extent to which *elevation* as well as denudation has been instrumental in giving rise to the present configuration of the ground. All geologists will admit that it must have been washed by the sea, up to a certain height at least, during the glacial submergence, or at

* The term ice-floe is here used for floating ice in general.

the time when the drifts with sea-shells of the midland counties were accumulated. To the north of Coseley, on the side of an eminence, there are what *appear* to be several raised coast-lines or sea-terraces which have preserved their horizontality to an unusual extent.

A part of Tettenhall and Tettenhall Wood stands on a Triassic escarpment. Its general slope is sufficiently steep to answer to a line of sea-cliffs, bevelled down by atmospheric action. Its summit is an approximately level old table-land, and its base is, in most places, unusually flat, especially to the north of Trescott, where the ground reminds one of a shallow sea-bottom. The principal facts on which a subaërialist would found his theory of the origin of this escarpment by a 'wash of rain,' would here appear to be wanting. There are even no rivers which could have acted as carriers, for the plain under the escarpment is only traversed by artificial drains, or the merest runlets. It must have been washed by the sea at the time when icebergs floated from the north towards the south, leaving the neighbourhood strewn with the wrecks of the hills of Cumberland or Scotland; and the sea-bottom could not have become dry land without this escarpment being subjected to the undermining action of waves, by which its continuous extension and abruptness were in all probability produced.

There are few parts of England so invested with the 'romance of geology' as the neighbourhood of Trescott. Sir Roderick I. Murchison long ago directed attention, in his 'Silurian System,' to the granitic boulders of this district. He was the first to show that a great part of West Central England is covered by the 'northern drift,' of which, I suppose, the Trescott boulders may be regarded as the most wonderful manifestation. On walking from Wolverhampton, one may see the trap and granitic drift increasing in the size and number of the fragments, until near Trescott they seem to reach their maximum development. Granitic boulders are found in other parts of Staffordshire, Shropshire, &c.; but with the exception of small stones, which may have been drifted by the sea, they are, I believe, everywhere limited to certain areas where they would appear to have been dropped by ice-floes. The inhabitants of Trescott would now probably open their mouths and stare, on being seriously informed that an iceberg, as large as a small hill, once showered down a host of ponderous blocks of granite and porphyry, where they can now raise their heads free from danger; and yet it seems as true that a district visitation of this kind once here occurred as it is that boulder-laden icebergs now traverse the North Atlantic Ocean. The theory of land-ice pushing boulders along in its march across a continent is here out of the question. How could land-ice have selected blocks of granite, porphyry, &c., pushed them all the way from Cumberland or from Scotland, and finally left them congregated in this particular spot, not only in family proximity, but unmixed with the débris of many rocks over which it must have grated during its intermediate course? Glaciers carrying both fallen and uprooted blocks may indeed have slidden down the valleys of Strathclyde,* and on reaching the sea-coast may have embarked as icebergs, with their freight of boulders; or islands of coast-ice, their bases charged and their surfaces covered with stones and blocks, may have been floated by currents in a southerly direction. The ice-floe which left the Trescott boulders, and ice-floes in other places, may have been relieved of their loads by foundering against or on rising ground,

* The ancient name of the district between the Clyde and the Mersey.

or by being left in quiet water to melt. The boulders near Trescott are principally granite, more or less syenitic, and porphyry exhibiting various gradations into trap. Nine out of ten of the larger boulders are granite or syenite. The porphyry reminded me very much of what I had seen in the Lake District. The trap did not seem to indicate any special locality. It generally assumed the shape of spheroidal or globular masses, with the original rough surface remaining. The smaller fragments of porphyry, granite, and syenite were more or less rounded; the larger blocks were generally, but not always, angular. Here and there fragments of metamorphosed rock, to which no particular name could be given, might be seen mixed with igneous boulders. The granite seemed to belong to the intrusive or eruptive, and not to the supposed metamorphic kind. I was surprised to find blocks of a kind of rock resembling the *elvan* of the neighbourhood of Bovey Tracey, Devonshire.

The boulders may be seen in great numbers in the walls of road-cuttings, mixed up with artificial ironstone slag. They have been gathered off the neighbouring fields, where they are generally found buried in a fine loam, which probably represents a boulder clay. The soil of whole fields has received a character from the detritus arising from the disintegrating and dispersing action of the sea on the fallen great icefloe-load; I say the action of the sea, for the weather cannot distribute stones on level ground, and the weather could not have deposited the loam in which the boulders are imbedded, for it contains extra-rounded small pebbles.

The finest display of boulders I have seen, occurs where two lanes enter the Bridgenorth road, a short distance to the east of Trescott. The largest boulder (hard granite) is about four feet by three. On the side of the lane, running in a northerly direction, or towards the above-mentioned escarpment, there are several blocks which the country people would probably call 'stunners.' I saw two at least five feet by three.

My principal discovery (if it can be called a discovery) consisted in tracing out distinct striations on at least twenty of the boulders. On a fragment of nameless rock (unless Mr. David Forbes can name it, after a chemical analysis) with an approximately slaty appearance, I saw scratches and fine striæ, both primary and secondary. The surface between the lines was slightly polished. On the surface of a large and blunted block of granite, partly concealed by other blocks, I saw a number of cleanly-cut parallel grooves. The surface between and around them was smoothed, and in some places polished. In several instances, the striæ ran for some distance conformably to the convex surface of the stone—a fact indicating plasticity in the force by which they were formed.*

Near Trescott I was fortunate in meeting with a very intelligent and thoroughly English gentleman, who remembered Sir R. I. Murchison's visit; who gave particular directions where boulders might be found; and who warned me against mistaking marks left by the grating of the plough for glacial striæ. He likewise informed me that he found it necessary, in uprooting the larger boulders, to dig all around them, and to subject them to horse-power. What a subject for a picture! A pair, or two or three pair of horses, with two or three unsophisticated peasants, trying hard to disinter an Eskdale (?) boulder from its grave of several hundred thousand years (Lyell): the former struggling

* Stones striated nearly all round are common in the boulder-clay of north-west Lancashire, and are, I think, only explicable by the action of coast or ground ice.

in real brute unconsciousness—the latter doubting the possibility of removing a stone, which according to their belief has not been moved since the creation! It would be a pity to disturb their ideas of the antiquity of the stone, for it was certainly entombed long before the creation of man. Compared with the period these boulders have slumbered in their beds of marine-glacial loam, the conquest of Britain by the Romans is an event of yesterday. In these beds they remained unmoved while the busy population of the neighbouring Uriconium lived and died, and while the very city became buried, and its site obliterated! In these beds many of the boulders will probably remain when the South Staffordshire coal-field has become exhausted; when the heaps of coal-mine rubbish (by which a new scenographical geology has been given to the district) may alone diversify the surface of a great uninhabited desert! I say *may*, for it is possible that these outscoopings of the bowels of the earth may become so triturated by atmospheric action as to nourish a somewhat luxuriant forest growth, similar to that which now marks the sites of the old iron-pits and cinder-banks of the Weald of Kent and Sussex.

XV.—AROUND IRONBRIDGE, AND TO THE SUMMIT OF THE WREKIN.

The geologist will find much to interest and not a little to puzzle him in the immediate neighbourhood of Ironbridge. First of all, he will be struck with the very narrow, deep, and steep-sided gorge through which the Severn finds its way for some distance in a south-easterly direction. In the comparatively wide and open depression to the north-west (including the lower part of Coalbrookdale) there are very extensive deposits of undoubted marine drift. In trying to explain the connection between this depression and the Ironbridge gorge, one is driven back to the period of the glacial submergence, for since then it is certain that the river in the wide depression has only excavated a channel in marine drift, and slightly deepened the gorge.

The stratigraphical structure of this district is complicated, and not easily explained in connection with denudation. The wide depression has been chiefly excavated out of Wenlock shale, and the entrance of the narrow gorge out of Wenlock limestone. The steep escarpments of Benthall Edge and Lincoln Hill are so similar in form, and so much in a line, as to suggest their continuity previously to the opening of the Ironbridge gorge. If so, the excavation of the deep and wide depression bounded by these escarpments could not have been the work of a river, for no river could then have found an outlet. Though the sides of this depression must have figured as a sea-coast during the glacial submergence, its general contour as seen from a distance seems more suggestive of the sweeping action of winding, deflected, and eddying currents, if not of waves of translation, which may have found a sufficient thoroughfare along the rising ground in the direction of Lightmoor on the one hand, and along the Severn Valley, or one of the valleys branching off towards Wenlock, on the other. It is, however, possible, if not probable, that the excavation of this depression may have been initiated by subaërial causes, and completed by sea-coast action. The narrow gorge may have originated in a fracture, causing an ‘ abrupt severance ’ of the rocks on both sides,* and this fracture may have been widened by marine currents. As we have no

* Sir R. I. Murchison's *Siluria*, p. 497, 4th ed.

reason to assume the existence of river-gravel under the marine drift of this locality, we are only warranted in supposing that the River Severn here first began to flow, after this drift was deposited, and after the gorge was opened.

Between Ironbridge and Bridgenorth the gorge of the Severn is of very irregular width, and on the eastern side there are several fine sandstone escarpments, one of which, near Apley, has no direct connection with the gorge itself. On some parts of these escarpments, traces of wave or current action at different levels can still be distinguished from the effects of weathering.

Since the time the Severn began to occupy the succession of open areas and gorges through which it flows between Buildwas and Bridgenorth, several land-slips have occurred. The Rev. Mr. Fletcher, of Madeley, long ago described one which altered the face of the country between Coalbrookdale and Buildwas. Between Ironbridge and the house of John Anstice, Esq., the north-east side of the Severn Valley has been broken down by land-slips, which in some places have left remarkably regular lines of cliff; and some might appeal to these occurrences as illustrating the origin of escarpments; but wherever a land-slip has here occurred, the slipped land may be seen underneath (if it has not been removed by human agency). No doubt in time it will disappear, but probably not sooner than the destruction of the superjacent lines of cliff.

To the Wrekin.—After crossing Lincoln Hill, the ravine called Coalbrookdale (if not seen before) comes most unexpectedly into sight. In passing along this ravine, the tourist will not fail to notice the striking monuments in the shape of ironworks, which man has here erected to the power he possesses of bending the laws of nature into submission to his intellectual skill.

In the upper part of the dale, the commencement of the channel excavated by the present brook, and its *distinctness from the general contour* of the valley, cannot fail to be perceived. The head of the dale would appear to have once been hemmed in by continuous cliffs or steep slopes. But several gorges have been made, in all probability by the small streams which now flow through them.

Instead of taking the Wrekin by the high road leading to Wellington, it is more interesting to walk across the country to Little Wenlock, and thence to the base of the south-eastern or steepest side of the Wrekin. You have no sooner commenced the ascent of the mountain than you encounter heaps of strewn débris, among which a kind of porous lava is very common. Stones, no doubt, still fall from the rocks above, but the bulk of this débris looks as if it had been accumulated under water. After scrambling up a slope at an angle of about 40°, you arrive at the Raven's Bowl, a crag with a very precipitous front, which presents every appearance of its having been undermined. In the neighbourhood a crag with a cleft called the Needle's Eye cannot fail to arrest attention. These crags consist of felspathic trap, which must at one time have been in a state of fusion. It could never, however, have cooled down into the form now presented by the crags. Rain would have caused a general degradation of the surface of the igneous rock, or left a series of minute gutters. The cliff like form may reasonably be attributed to the sea, which at one time undoubtedly washed the sides of the Wrekin. The Needle's Eye, especially, seems to have been formed, or at least modified, by wave-action.*

* As a large proportion of the stones found in the Severn Valley marine drift must have come from the Wrekin (see Mr. Maw's paper, *Quart. Journ. Geol. Soc.* Jan. 20, 1864), it is simply a fact that sea-waves or currents once attacked and carried away stones from the sides of the mountain.

The Wrong Thing in the Wrong Place.—On the highest part of the Wrekin (during a previous excursion), I saw a phenomenon—not geological, and certainly not picturesque—which happily is seldom witnessed in such aërial situations. A party of pleasure-seekers from the Black Country had just arrived, but instead of being filled with wonder at the truly magnificent prospect around them, they immediately sat down and commenced playing cards and drinking gin. Now everything has its time and place, but this was certainly neither the one nor the other for card-playing; and the circumstance furnished a grievous illustration of how far the nobler tendencies of the human mind (among which must be reckoned the admiration of natural scenery), may be subjugated, by allowing the animal excitement connected with a vulgar recreation to become the great object of life. Such a desecration of one of Nature's temples is not, however, altogether without a geological value, for a knowledge of the circumstance may prevent the tyro from mistaking broken fragments of gin-bottles for specimens of vitreous lava!

The descent from the Wrekin may be made by walking along the ridge in a north-easterly direction until you arrive at the refreshment house. On this part of the mountain, if not at a higher level, you may find many fragments of saccharine quartz-rock, lying loose on the surface, or imbedded in the soil. Were they washed up by waves during the gradual subsidence of the Wrekin under the sea, or do they indicate the former existence of metamorphosed Caradoc sandstone strata on the spot? Was the truly erupted boss of the Wrekin once buried under a mass of sedimentary rocks which have disappeared through denudation? Whatever difference of opinion there may be on these questions, all must admit that denudation has cut deeply into the igneous nucleus of the Wrekin. The deep and winding pass which separates the Wrekin, strictly so called, from the Ercall, has evidently been scooped out, or at least deepened and widened by the action of water, but as the ground declines at both ends, it could not have been formed by a fresh-water stream. There is here no necessity for applying Professor Jukes' theory of the former existence of ground higher than one end of a gorge, as a watershed for a stream, for he admits that passes or gaps on the crests of hills may have been excavated by marine currents.

XVI.—AROUND CHURCH STRETTON, AND UP THE LONGMYND GULLEYS—REFLECTIONS ON A WORM-BURROW.

There are very few spots in South Britain in which a greater variety of scenery combining abruptness with loveliness can be found than in the immediate neighbourhood of Church Stretton, Shropshire. The town stands in a thoroughfare pass between the Longmynd on the W., and the Ragleth, Hazler, and Caradoc range of hills on the E. The bottom of the pass is so flat that its culminating level cannot be precisely ascertained. It divides to the S. of Church Stretton, the flattest part winding between a central knoll and the Longmynd. This part is called the World's End. On entering it you are faced by a large, smooth, shallow concavity, on the side of the Longmynd, along the base of which the road curves round. On the left of the road a very small brook can scarcely be said to flow, though with difficulty it finds its way through a half-desiccated, peaty swamp.

A great part of the pass, especially in the neighbourhood of Church Stretton, has been found to be covered with an angular drift, nearly all local, and distinct from the rounded drift farther N. The fragments would appear to have come chiefly from the Longmynd, and the question arises, Are they the general sweepings of the mountain, or have they been chiefly derived from the deep gulleys?

The tourist ought to make a point of ascending some of these gulleys. The scenery, especially in Ash's or Ashes Gulley, is almost unique. The sides of the hills rise up from the bottom of the gorge, at angles of quite 55°, which gradually decrease upwards till the slopes sweep round conical eminences or the ends of short ridges. Near the mouth of Ashes Gulley there are large boulders of grit, and I saw two of trap, one of them at least five feet long. The brook could never have carried these boulders to the positions they now occupy.

Fig. 81.

Stream-channel superimposed on a previous depression (Longmynd).

Where the rough-sided channel of Ash's Brook commences can be clearly perceived. (See Fig. 81.) It is obviously an infringement on the smooth-sided depression or pass on which it has been superimposed, and the same remark applies to some of the lateral or tributary stream-channels. These channels not only present a fresh-looking brink at a certain height above the stream, but they wind, quite unconformably to the hill-sides above. The previously-existing depressions which the Longmynd streams have deepened (in some places 200 or 300 feet at least), would appear to have been a series of intersecting passes. A linear coincidence between two passes on each side of a gulley may frequently be observed. The pass on the western side of Round Hill, and the one on the opposite side of Ash's Gulley, may be mentioned as an example. The Longmynd stream-gulleys are merely exaggerations of passes. In the main-gulleys the ‿-shaped floors of passes have been worn down by streams to V-shaped ravines, and in the tributary gulleys the ends of the intersecting passes have been deepened by streams, the depth gradually increasing towards the main gulleys. The Longmynd passes must at one time have been the depressions of the deeply-undulating summit of the mountain. The extreme flatness of the tops of many of the eminences would, however, appear to indicate that these depressions were excavated out of a uniformly level or sloping table-land. The cause of the excavation must have been capable of rounding and smoothing the sides of eminences, and communicating a curvilinear form to the depressions. Oceanic currents, or currents caused by sudden upheavals or depressions of the sea-bed, would be more capable of producing this effect than any other cause with which we are acquainted. Where the sea left off, fresh-water streams commenced, and in the Longmynd district they have left *striking indications of their excavating power*.* The final contour received by the Longmynd gulleys, however, cannot be well explained without supposing a comparatively recent submersion, during which the mouths of the gulleys were

* The superimposition of stream-valleys on valleys previously existing, was noticed by the Author several years ago, and referred to in the *Geol. Mag.* for July 1865, p. 303.

widened, and the form of ground which characterises the west side of the great pass of Church Stretton continued up the sides of the gulleys.

Having come up Ash's Gulley, and arrived at the pole on the continuous ridge called the Portway, the tourist may next go down the Devil's Mouth (a road-cutting through a ridge above Church Stretton), or should he prefer it, he may scramble down the Lightspout Gulley. The Lightspout Waterfall, though small, is a truly picturesque object. The gulley below it is V-shaped. The bottom only affords room for the brook and a footpath. The greater part of it may be safely regarded as a specimen of a genuine stream-valley.

At the Lightspout Waterfall, the geologist may for once consider himself justified in giving reins to his imagination, for here, some time ago, Mr. Salter discovered the burrows of worms, in strata previously regarded as unfossiliferous. One of the species has been called *Arenicolites didyma*. The geological advocate of sober prose might think the idea of apostrophizing this annelid uncalled-for and far-fetched; and yet there is something truly wonderful (if anything can be called wonderful) in the preservation of the exact specific shape of the burrows left by worms which must have lived many millions of years ago, before the vast pile of strata, until lately regarded as embracing nearly the entire crust of the earth, began to be amassed. Why apostrophize a mummy which was embalmed only yesterday, and look with contempt on the memory of these poor worms? Does antiquity confer a claim to consideration? These worms can boast of an antiquity transcending that of any organic form which has crept on the face of the earth *—an antiquity in comparison

* Any possible discoveries in the Huronian or Laurentian strata are here left out of consideration.

with which that of nations and races of mankind sinks into insignificance. In looking back to the overwhelmingly-remote period, when the *Arenicolites didyma* burrowed in the sands of Cambrian sea-shores, earth's cities and empires seem like passing foam-bells on the tide of ages. Does immortality render a being an object of wonder and admiration? Here we have immortality worthy of the name, securely perpetuated in the rocky framework of the 'everlasting hills.' The tenements these worms constructed in Cambrian times have endured through the tear and wear of a thousand geological revolutions, while the most gorgeous palaces erected by human hands have, in a few brief years, been erased from being. How vain does the ambition of an Alexander or a Cæsar appear when contemplated within the roar of the Lightspout Waterfall, amid the lapidified mansions of the *Arenicolites didyma*.

XVII.—FROM SHREWSBURY TO THE STIPER STONES.

The great plain of Shropshire stretches to the base of the NW. declivity of the Stiper Stones ridge. It rises up like an old tidal zone, gently, uniformly, and smoothly, to where the steep part of the escarpment commences. At Minsterley, and for some distance up the gradual slope, the drift is stratified and variegated, and the stones it contains generally lie flat. At first more or less rounded, they become more angular as we ascend, until they graduate into the chip and splinter drift covering the face of the escarpment. In the right-hand concavity of the hollow (midway between a cwm and a valley), above Snailbeach, there is an accumulation of fine angular detritus. The fact that the easterly continuation of the slope has been stripped bare, furnishes a negative evidence that this accumulation is not the mere waste of the ground above it, while its position and form favours the supposition that it was carried along by a sweeping agency and here arrested. This supposition is confirmed by the fact that the accumulation of fine angular detritus graduates into a tongue of rounded drift containing patches of sand, on the west side of the entrance to the valley. Other facts and considerations show that the sea must at least have washed the base of the NW. escarpment of the Stiper Stones ridge.

Farther to the SW. this escarpment has been indented in a manner that no one would suspect, and scarcely believe, until he came on the brinks of the indentations, and actually witnesed their profundity. They are known by the names of the Crow's Nest, Mytton Dingle, and Perkins' Beach. That they are the effect of denudation cannot for a moment be doubted. The Crow's Nest partakes of the shape of the letter T. Its back steep slope is nearly conformable to the dip of the strata (Llandeilo shale, &c.). The longitudinal part of the excavation runs along the strike, and the transverse outlet gorge crosses the strike. Such hollows cannot easily be explained by sea-coast action; and the same remark applies to the two neighbouring hollows, though in them the sea would appear to have rounded off projections, and hollowed out recesses. All three were probably initiated by rain and its 'resultant streamlets,' and the two latter (especially Perkins' Beach) enlarged and rounded out by the sea during the glacial submergence.

The summit of the Stiper Stones ridge is approximately level longitudinally, and gently curved transversely. (See Figs. 82 and 83.)

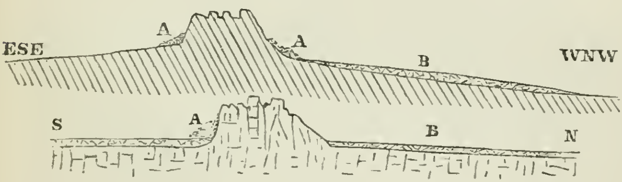
The origin of the Stiper Stones (which perhaps average about thirty feet in height) consists in their having been left by a destroying agent which both tore away and swept away the once intervening rocks. They have evidently been encroached upon by a planing agency capable of shaving off the ends of highly-inclined strata. In places, the smooth and flat ground, covered with

Fig. 82.

Rocky Projections, called the Stiper Stones, from the NE.
(Siliceous Sandstone passing into crystalline Quartz-rock—from 1,500 to 1,600 feet above the sea.)

herbage, comes up to the base of the nearly perpendicular cliff, especially on the south-east side. The flat spaces between the rock-masses are partly so in consequence of the covering of angular fragments having been

Fig. 83.



Transverse and Longitudinal Sections of the Stiper Stones Ridge.
AAA Recent screes. BB Transported, deposited, and levelled angular débris.

levelled down, as if a gigantic roller had passed over the hill. On the east and south-east side, the ground adjacent to the rocks has in general been swept clean. On the west and north-west side there are wide expanses of coarse débris, which have been smoothed down so as to present a uniform gently-sloping surface. Not one out of a thousand of the fragments or blocks which have been scattered between the rock-masses, and along the ground to the W. and NW., could have fallen from these masses to their present positions, and few of them appear to be directly *in situ*. They have evidently been carried, accumulated, often piled on each other, and distributed so as to fill up hollows, and finally smoothed down to a uniform surface, by a cause capable of detaching and transporting fragments and blocks; for here there are few or no signs of granular dissolution. The cause would appear to have been principally directed from the SE. The rocky projections called the Stiper Stones, may, during one stage of the denudation, have been parts of a more or less continuous wall of quartz-rock, which was afterwards breached through by the agency which scattered, accumulated, spread out, and levelled down the resultant débris. All that frost and rain have done since the Stiper Stones were fashioned, and the neighbouring ground smoothed down, has been to shatter down parts of previously-existing cliffs, and form a sloping talus of fragments by which the bases of the cliffs are concealed. The original formation of the cliffs by undermining, and the removal of fragments, and the levelling of the transported detritus, may have been partly the work of sea-waves. But a general survey of the phenomena presented by the summit of the Stiper Stones ridge would *seem* to point to the conclusion that a great rush of waters (if not a flow of ice), once occurring, or a number of times repeated, must have crossed the ridge in a direction from SE. to NW.,* swept the ground comparatively clean on the south-east side, and left the main mass of débris on the north-west or lee-side of the mountain.

* For a full account of the stratigraphical structure of the Stiper Stones districts, and views of the surface of the Stiper Stones ridge, see Sir R. I. Murchison's *Siluria*.

XVIII.—FROM WEM, TO THE HAWKSTONE AND GRINSHILL CLIFFS.

A GEOLOGIST has scarcely left the town of Wem (Shropshire), before the idea of his treading on an old ocean-bed becomes not only a probability, but a certainty. Nearly the whole of the flat surface between Wem and Weston is covered to a considerable depth with sand and pebbles; the latter in many places very small, and resembling the fine shingle of our present sea-coasts. They may be partly of Triassic derivation, but most of them would appear to have come directly from Wales and the Welsh borders, or from the north. They often consist of thin flat fragments of a kind of sandstone, only partly rounded. Here and there, but rather sparingly, boulders of red and white granite, felspathic trap, &c., may be seen. I noticed one in Hawkstone Park, at no very great distance from the cliffs. A few hundred yards from the latter, on the side of a deep, but now nearly dried-up pool-basin, I saw a considerable thickness of fine shingle under a bed of sandy loam. Throughout Hawkstone Park, including the top of the cliffs, in some places, this shingle may be found at intervals under or graduating into sandy loam, and this loam is seldom free from a few thinly-scattered pebbles. Near the base of the cliffs the soil is very sandy, and the sand may have been partly if not principally derived from the decomposition of the cliffs; but as it forms a smooth continuous slope along their base, or is distributed on rising ground at a greater or less distance from the cliffs, it could not have been carried and deposited by rain. In many places, on the contrary, it presents the appearance of having been washed up, if not blown up, against the base of the cliffs. The remarkable mound called the Giant's Grave consists to an unknown depth of sand which no kind of pluvial action could have heaped up. On the summit of the cliffs there is a greater or less thickness of sand and sandy loam, but so far from graduating into the rocks beneath, as if it were a disintegration *in situ*,* a well-defined, smoothed, and rounded surface of rocks becomes exposed as the sand is removed. The cliffs in Hawkstone Park consist of members of the new red sandstone formation, and nowhere perhaps in Great Britain does this formation assume such sublime and picturesque forms. Here, indeed, it rivals in this respect the millstone grit of Yorkshire and Derbyshire.

The wonderfully level pebbly and sandy plain of Salop is suddenly varied by rising ground commencing on the south in Grinshill, extending northwards to Lee Hill, and then running in a north-easterly direction. This rising ground is escarpmented, and cliffed at intervals, towards the south and east. It terminates towards the north, and culminates in Hawkstone Park, part of which is a table-land of considerable elevation. This tableland gently rises in a southerly direction, until it is very abruptly bounded by a cliff-line, which has obviously been worn back by an undermining agent. The cliffs run nearly west and east for about a mile, and then turn round towards the north, where I had not time to follow them. Near their western end there is a detached eminence, like an offshore island, called Red Castle Hill, in a part of which the truly wonderful cylindrical cavity called the Giant's Well has been artificially excavated. North of it there is another eminence, not quite separated from the main line of cliffs.

* The sand covering a great part of Grinshill, is of a colour and nature distinct from the rock beneath.

Red Castle Hill.—This eminence has been shaped into a variety of typical sea-coast forms. Fine cliffs of sandstone, partly covered with white moss, rise abruptly to a great height. Here and there they have been rounded and hollowed, irrespectively of structure, excepting where extensive faces of rock retain the flatness of their jointage planes. In several places I noticed semicylindrical undercuts, and in one place a small cave, with a smooth semicircular roof; the cave itself nearly filled with sand and fragments of sandstone, which must have been washed in. The cliffs present rocky projections, with small creeks or curvilinear cwms intervening.

Grotto Hill.—This hill is joined to the main line of cliffs by a ridge through which a passage for a road has been artificially excavated. In this passage I had an opportunity of contrasting rock-surfaces formed by man with those produced by natural causes. Not very far from the summit of this hill there is a natural passage or channel between fifteen and twenty feet in average depth, and perhaps about seven or eight feet in breadth. Its length, as far as the commencement of the artificial excavation or dark passage leading to the grotto (with which we have at present nothing to do), is at least 150 feet. It is said to have been once filled with rubbish, which some time ago was cleared out.* It is vulgarly supposed to have been formed by an earthquake, but a transverse section of it renders it evident that it has been scooped out by water, with the exception of the lower part, which has been levelled so as to form a footpath. On the summit, and near the brink of the cliff, on the south side of Grotto Hill, imperfectly-developed rock-basins may be found, and the large faces of rock forming the cliffs underneath have been moulded into very

* During the clearing-out process portions of this passage may possibly have been modified.

striking forms. The cliffs here are perpendicular, excepting where they overhang, and the height above their immediate base cannot be much less than 100 feet. In any part of the world they would be considered magnificent specimens of rocky scenery.

The Main Line of Cliffs.—These cliffs run along what is called the Terrace. A pathway, near their western end, runs obliquely up their face towards their summit, under some of the largest overhanging solid masses of rock I have yet seen. A passage about forty feet deep and twenty feet wide conducts the visitor to the brink of the cliffs. The rocks on the side of this passage are rounded and smoothed in the usual fashion. The table-land above rises towards the east, but there is a considerable curving down to where the cliff-line commences. On walking along the brink of the cliffs and looking down, one beholds, half-concealed by trees, a succession of small creeks, coves, and capes, most intensely sea-coast-looking in their contour. The creeks generally run obliquely down the cliffs, and are easily explicable by reference to a direct undermining action, assisted by the backward rush of waves, thrown up on the summit of cliffs during storms. The coves have evidently been retrogressively excavated. In one place a headland has been half decapitated, leaving a detached pyramidal pillar, which can only be seen from certain points of view through the thick vegetation, which has aided in protecting this hoary monument of the past from the disfiguring influence of the atmosphere. The Terrace escarpment is at least 250 feet in height, though only the upper part is cliffed.

Cwms of Hawkstone Park.—Next to the rounded and hollowed surfaces of rock, and the passages with rocky walls, the cwms or small coves are the most marine-looking features of the Hawkstone slopes and cliffs. There are several on the sides of Red Castle Hill; and, in the main line of cliffs, at least six or seven, exclusive of creeks, may be found at intervals. In one place three cwms are separated by rocky edges, thus mimicking the more majestic specimens of these phenomena in Wales. The latter, however, are not more perfect or curvilinear than some of those in Hawkstone Park. On the slope facing the main escarpment there is a succession of cwms as regularly shaped as if they had been turned out in a lathe. On the main escarpment they are generally semi-basin-shaped, with a rocky interior wall.

Grinshill.—This insular hill (about three miles south of Hawkstone Park) may be seen from a great distance. It rises above the plain, on its south-eastern side, to a height of at least 400 feet. This plain, as far as the Wrekin, is remarkably flat. Grinshill rises very abruptly, in the form of a cliff-crested escarpment. Towards the north, the declivity is very gradual. On this declivity there is a covering of fine sand, with fragments of sandstone, which overlies smoothed and rounded rock-surfaces. The sandstone composing the hill (chiefly fine white quartzose sandstone), excepting in the quarry towards the east, where the stratification is very uniform, dips slightly in various directions, and has apparently been much disturbed. At intervals the main mass is crossed by bands of quartz-rock, a few feet in width, which run south and north, and the laminæ of which are nearly vertical; a phenomenon I merely notice in connection with the fact that these bands have nowhere influenced the denudation, excepting where they form slight rocky projections on the summit of the hill. The cliffs are perhaps about forty feet in average height, with sloping ground underneath. Their denudation, in detail, has proceeded irrespectively of dip or strike. The strata generally dip longitudinally in the face of the cliffs; sometimes away from the cliffs, and often towards them. The Hawkstone features, such as creeks, coves, rounded projections and recesses, honeycombed surfaces, and cleanly-swept bases, are here repeated. On looking down on the perfectly flat plain on the south-east, the spectator may well feel himself constrained to ask, If a river has planed down such a uniformly-continuous surface, as far as the Wrekin in one direction (about twelve miles), and much farther in other directions, why may not a river have deposited the mass of sandstone of which the plain consists? The breadth of the depositing power of an agency must in general be equivalent to that of its denuding power. Why, therefore (in the absence of organic remains) have recourse to rivers in explaining phenomena of denudation, and to the sea in accounting for co-extensive phenomena of deposition?

Grinshill cannot fail to arrest the attention of the traveller by railway; but at a distance he will be unable to form any idea of the rocky scenery of Hawkstone Park, owing to its being almost entirely concealed under a mass of luxuriant vegetation.

XIX.—AROUND KESWICK.

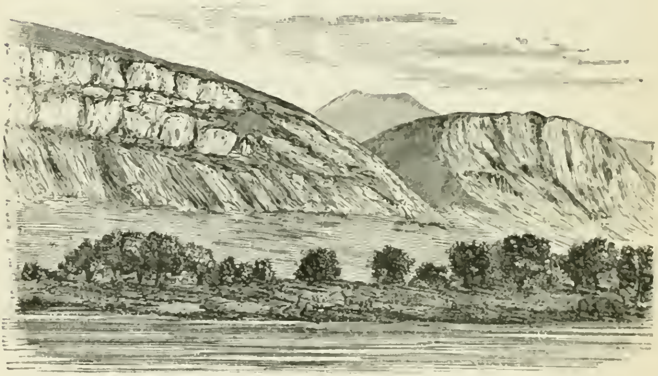
To the south and west of Keswick the hills are so near to each other as to suggest the idea of dwarfishness. If an ordinary hilly region of a certain diameter were to be laterally compressed so as to make it occupy, say one-fourth of its former area, its heights and hollows one-fourth of their former breadth, and their slopes four times their former steepness, it would resemble the scenery of this part of the Lake District. On looking south from the rocky eminence called Castle Head, the number of heights and hollows within a small compass produces a bewildering effect. But it ought to be remembered that this model-looking scenery occupies the same space, and makes the same impression on the retina of the eye, as a group of gigantic hills and valleys situated at a greater distance—with this difference, that the outlines of the latter appear softened down. On one of those very clear days, however, which are common among the Alps, a mountain 5,000 feet high above its own base appears so near the spectator as to make it seem like an eminence of only a few hundred feet. The superiority of Alpine to Cumbrian scenery may therefore in some respects be easily overrated.

On coming nearer to the details of the scenery south and west of Keswick (on the north the outlines of Skiddaw are on a truly magnificent scale), we find that they are not so dwarfish, after all. The fine line of cliffs, called Wallow Crags (see Fig. 84) cannot be much less than 1,000 feet higher than the level of Derwent Water, and in Borrowdale the height if not the breadth of the cliffs is very considerable. Indeed, the cliffs of the great mass of rock called Eagle Crag are truly majestic, and will bear comparison with many Alpine precipices. The Goat Crag facing the west side of Castle Crag, is a very fine specimen of a bare, raked, and furrowed face of rock. The Bowder Stone is an unusually large specimen of an isolated block of rock ;* and much more might be said in favour of the *magnificence* of the scenery of Borrowdale.

* In Hudson and Wordsworth's *Guide to the Lakes* it is stated to be 62 feet long and 36 feet high.

The walk, drive, or ride from Keswick to Rosthwaite discloses scenery which generally transcends the most sanguine anticipations. As regards stratigraphical structure the district is more puzzling than interesting. Greenish-grey rocks, consisting of slate, grit, and breccia, alternating with beds of metamorphic or volcanic origin, change their character, or graduate into each other, within so small a compass as to defy particular names being always given to small specimens. The variety in the hardness, softness, composition, and dip of the rocks has enabled denudational agencies to

Fig. 84.



Part of Wallow Crags, and Falcon Crag.

leave a sudden succession of abrupt inequalities.* The surface-configuration embraces almost every type of scenery with the exception of the cwm, strictly so called. Specimens of the latter, however, may be seen in the valleys between Borrowdale and Newlands.

The waterfalls in the neighbourhood of Keswick are the most likely to disappoint the tourist. Having never had very much faith in waterfalls as denuding agents

* See *Longitudinal Valleys, &c.*

(for reasons stated in a former part of this work), I was not much surprised to find that those of Barrow and Lowdore still seemed to be running over the old sea-escarpment, much in the same fashion as they probably did when the plain of Keswick was an inland sea. These waterfalls, according to the subaërial theory, ought ere now to have receded a considerable distance from the eastern escarpmental boundary of the plain of Keswick. Watendlath beck (the present Watendlath beck, at least) gives no evidence of its being more than a usurper of Watendlath ravine. During the greater part of the year its denuding power is small,* but after heavy rains and the melting of snows, it transports previously loose débris, and perceptibly modifies its channel. Then Southey's poetical alliterations are to a great extent applicable to the fall of Lowdore. At the time (May 1864) I saw this fall, it made so unimpressive a display of its denuding power, that the recollection of it has since suggested the following parody on a part of Southey's celebrated poem :—

> The cataract weak,
> With aspect meek,
> First creeps along
> The stones among,
> Through which it peeps,
> Save where it sleeps ;
> Then sputtering, fluttering, and muttering,
> And dallying, sallying, and rallying,
> With no downpour,
> Or any uproar,
> The water steals o'er
> The slope at Lowdore.

* Not very far from its source in Watendlath tarn it forms a small cascade, which has ground out a basin and a circular perforation. The basin is sometimes nearly filled with pebbles.

XX.—FROM CONISTON TO TILBERTHWAITE, GOAT'S WATER, THE OLD MAN, AND GREENBURN—TWILIGHT CONTEMPLATIONS.

The Coniston group of hills is separated from the great mass of mountains in the Lake District by the Duddon and Little Langdale valleys, and the connecting pass called Wry Nose. In this group you see the whole series more or less epitomized. It embraces within an area three and a-half miles in diameter the most choice specimens of surface-configuration, including ridges, edges, peaks, escarpments, cliffs, cwms, tarn-basins, passes, valleys, gorges, drifts, and glaciated rock-surfaces.

From Coniston to Tilberthwaite.—As you walk along Yewdale in a northerly direction, you are struck with the bare rocky grandeur and magnificence of a range of cliffs on the left-hand side. Their average height above the valley is between 900 and 1,000 feet. Their summit is an irregular table-land with alternating rocky ridges, bosses, and peat-mosses. At the head of the main valley, and facing the east, Yewdale Crag presents a continuous and very steep face of bare rock, which has been left by a process of denudation disregarding the strike of the beds. The base of the whole range of cliffs is approximately level, and is covered with gravel more or less rounded, which graduates upwards into angular detritus. About a mile and a-half from Coniston, Tilberthwaite Valley branches off to the NW. It is bounded on the NE. by a lofty mass of bare rock, called Raven Crag. At the mouth of the valley there is a plateau of drift, which at one time may have extended across, and may have been breached by a valley-glacier, or by the present stream. An enthusiastic devotee of ice might call this a glacial moraine, but the question arises

What is a Glacial Moraine?—Is it an abrupt ridge or mound, with surface more or less irregular, and covered with angular blocks which are merely the upper part of the accumulation? Has it any peculiar shape—such as a ridge of débris running along the side of a valley, or a semicircular ridge running across a valley? Is a moraine the matter which has fallen on the surface of a glacier, and which during its shrinkage has been left behind? or is it a subglacial accumulation pushed forward and left without being over-ridden, or after being over-ridden, during the contraction of the glacier? Is a moraine a mixture of supraglacial and subglacial débris? Is there no distinction between a deposit of boulder clay, sand, or gravel, and a moraine? Unless, with Mr. Jamieson, the great Scotch glacialist, we limit the term moraine entirely or principally to an accumulation of angular supraglacial débris, we cannot avoid making serious mistakes in classifying the superficial formations of the earth's surface. With the exception of perched blocks (some of which may indeed have been left by floating ice, or by ordinary wave-action, as on the Great Orme's Head) and surface-débris in certain positions, there are few decided indications among the Coniston Fells of the action of district or valley glaciers. (See *sequel*.) The grass-covered plateaux, terraces, gradually-swelling mounds, and smooth slopes of the Coniston valleys are found, where sections have been exposed, to be made up of *drift*—as much drift as any to be found in any part of England or Wales. The drift of Tilberthwaite is mainly lower boulder-clay of a yellowish-brown colour, nearly as hard as rock; full of stones, generally of moderate size; and only at intervals containing large boulders or groups of boulders, these boulders in almost every instance striated. It presents, not a degenerate equivalent of the lower boulder-clay of the Lancashire plains, but an intensely typical development of the principal characteristics of the latter, excepting that the stones are not so much rounded. Arguments might be brought forward in favour of its accumulation and induration by the ponderous march of a great flow of land-ice, which at first buried and afterwards nearly filled the valleys; and arguments might be advanced in favour of its being a marine deposit. As regards the Coniston valleys, I think a conjoint agency will best explain the phenomena. As the land sank beneath the sea, the retreating ice may have supplied the sea with the striated blocks and the clay, which the sea may have deposited and wedged into a compact mass. The boulder-clay of Tilberthwaite presents indications of its final accumulation under water, such as the occurrence of cleanly-washed groups or pockets of stones of approximately uniform sizes, &c. Beneath it in many places (in other places it rests on a rough surface) the rocks are beautifully smoothed, polished, and striated.

Culminating Level of Tilberthwaite.—The highest part of Tilberthwaite Pass is a wide and approximately level area. The main stream approaches the pass from the SW., through the picturesque chasm called the Gill; but on reaching the pass, instead of continuing to flow in the same direction, or towards Little Langdale, it bends suddenly round, and flows in a nearly opposite direction. At the bend it cuts through a narrow ridge of rock which crosses the pass, in apparently the most perverse and inexplicable fashion—inexplicable excepting on the supposition that the breach was made for it by the sea. The stream running towards

Little Langdale, as if equally determined with its rival to show that it had no share in the excavation of the wide summit-area of the pass, likewise makes its entrance in a direction nearly the opposite of that in which it flows after suddenly changing its course. Near the middle of Tilberthwaite Valley, on the south-west side, there is a boss of rock which has been minutely hollowed and smoothed up the valley, as if by sea-action.

From Coniston to Goat's Water.—The Walna Scar road has to be followed for about two miles. It leads over a moor which is bounded on the NW. by the steep slopes of the Old Man, and is crossed by several shallow flat-bottomed passes, containing peat-bogs or tarns. This moor is covered with drift, the main part of which I believe to be equivalent to the upper boulder-clay. Its surface is dotted over with erratic blocks, which may have been dropped by floating ice. On reaching the shallow and wide valley between the moor and Walna Scar, you encounter great accumulations of drift, in which the stream from Goat's Water has cut a channel a few yards in depth. This drift is partly hard lower boulder-clay, and partly gravelly earth. Before leaving the Walna Scar road for Goat's Water, a striking concavity in the face of the Walna escarpment strikes the eye. The frontal barrier of this cwm is about 1,800 feet above the sea, and its back wall is 437 feet higher. Behind the barrier, but invisible unless viewed close at hand or from above, Blind Tarn quietly reposes. It is, perhaps, the only pool of water with a large regular basin, in South Britain, which has no outlet. I had not time to scramble up to it, but I fancied I could see a spring seven or eight hundred feet beneath it, which might be the egress of an underground stream. But this theory of the mode of existence of the Blind Tarn would degrade the fine cwm in which it is situated to the rank of a huge swallow-hole.

After leaving the Walna Scar road, you follow a quarry cart-road for about half a mile, which brings you within a short distance of Goat's Water; but this short distance must be traversed either over bogs or projecting rocks—the latter (though almost impassable except to hardy pedestrians) to be preferred. Goat's Water lies at the extreme bottom of a deep cwm with a narrow entrance. I could see no decided traces of glaciation in any part of it. The great N. and S. flow of land-ice (see *sequel*), must have done some work here, but the action of the sea may have obliterated its effects. The cwm being comparatively open at its northern end (Goat's Hause, 2,150 feet above the sea), may have admitted not only of an increased velocity of tide along its length, but winds may have been sufficiently strong to awaken furious billows. When I visited it, the gusts of wind from the N. were so forcible that my companion was violently dashed against me, an injury to the chest being the result. At Coniston, I was assured that anglers are here sometimes lifted from the ground by sudden gusts of wind, and that the waters of the tarn are swirled half way up Dow Crag. At the time of my first visit, clouds of spray were forced up into the air from the lower end of the tarn. The basin of Goat's Water seems as if it had been excavated in solid rock, and afterwards nearly filled with the loose angular blocks and fragments which may everywhere be seen running under the water. At its northern end there is a tract of transversely-level ground which slopes towards the water. Two small streams flow down this slope, but they have made scarcely any impression on its smooth and flat contour; and yet some geologists would credit these streams with having excavated the cwm.

Goat's Hause, above it, is a level boggy area, like most mountain passes in the Lake District and Wales. Dow Crag (see p. 171), on the western side of Goat's Water, rises to a height of about 900 feet. It consists of several stupendous masses or broad columns of rock, separated by yawning, and, in most lights, black gulleys or rakes, which towards the top of the ridge form deep indentations. The columns are about 500 feet high, generally nearly vertical, and in some places overhanging. Between their bases and the lake there is a steep scree-strewn slope.

From Coniston to the Old Man.—Above the plain on which Coniston stands there is a deep excavation in the face or rather heart of the Old Man, which consists of five plateaux or concavities, with intervening steep slopes or cliffs:—Coniston Copper Works plateau, 600 feet above the sea; Lower Paddy End plateau, about 800 feet; Upper Paddy End plateau; Pudding Cove, 1,150 feet; and Low Water Cwm, 1,790 feet. The first has a level floor of drift, and the same remark applies more or less to the second. The third has a frontal ridge with two outlets, behind which there is a flat boggy area of considerable extent. Pudding Cove has a high rocky barrier breached in the middle. On one part of this barrier there are two blocks, each about 20 feet in diameter. On walking along the frontal ridge towards Lever's Water, I saw a split block resting on a rounded rocky prominence, as if it had been dropped from floating ice. Between Pudding Cove and Low Water Cwm there is a precipice 600 feet high, down the face of which the small stream from Low Water slides and tumbles. It has not, however, succeeded in making more than a mere rut of a channel, though, according to the retrogressionists, it ought by this time to have made some display of its denuding power. On approaching Low Water you find the rocks in front of it more or less rounded, but chiefly in an up-hill direction. On the brink of the precipice these rocks form a barrier to the Low Water plateau, excepting where the stream flows through a breach. Behind the solid barrier there is a small peat-bog, apparently in a rock-basin. Farther back, a ridge of large angular blocks (one of them 24 feet long), evidently a glacial moraine, runs across the cwm, and acts as a direct barrier to the tarn. The walk from the tarn to the top of the Old Man is exceedingly steep. The Ordnance pillar of stones stands on the highest point of

Fig. 85

Low Water Cwm, under the Summit of Coniston Old Man.

a ridge, from which you look down into Low Water, over a precipice about 900 feet high. The ridge slopes steeply on the other, or Goat's Water side.

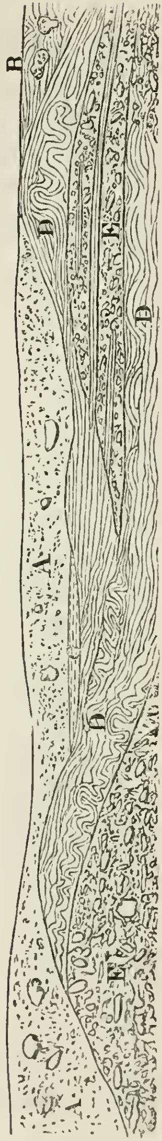
Glaciated Rock-surfaces. — During the ascent from Coniston to Low Water one meets with an almost constant succession of rounded, smoothed, polished, and striated rock-surfaces. Before reaching the Coniston Copper Works, on the right-hand side of the valley, the glaciation is on a very extensive scale. I was not surprised to find that the most strongly-marked striations ran N. and S., or obliquely across the valley, while a secondary series ran nearly NNW. and SSE., or along the valley. Higher up the valley, behind the Coniston Copper Works, and on the south side of Pudding Cove, the rocks have been striated N. and S. —in the former locality obliquely down-hill; and in the latter up-hill, with the glaciated sides of the bosses looking down towards the N., and the jagged sides looking up towards the S. The north and south striæ must here have been caused by a great flow of land-ice ignoring hill and valley.*

Distinction between Drift, Moraines, and Screes.—On walking from Coniston towards the Copper Works, and before getting into the regular course of the valley, three fine sections of gravel may be seen at an elevation of about 400 feet above the sea. They occur in positions to which no valley glacial action could have had access:—1. Rudely-stratified gravel, with many thoroughly-rounded stones, some as round as cannon-balls, and a few boulders, about 12 feet thick; a little 'pinel' or lower boulder-clay underneath. 2. Beds of clean sand and gravel, waved and contorted, at least 20 feet thick; stones much water-worn. 3. Finely-laminated sand, &c., with capping of red boulder-earth. Close by, the rocks present abrupt and smooth undulations, as if sea-worn, not striated. On nearly reaching the level of the

* This flow of ice must have smoothed the summits and higher slopes, as well as the valleys of the Coniston Fells. But as scarcely any traces of ice-action are now to be found at very high levels, as the action of streams is there at its minimum, as mere rain cannot denude hard rocks, and as little débris referable to frost is there to be found, excepting where cliffs or abrupt inequalities previously existed, it may be surmised that the effects of ice-action were effaced by the sea. The more elevated parts of the Lake District must have been peculiarly exposed to sea-action during a deep submergence of the valleys; and on highly-inclined strata, or on igneous rocks, both waves and currents would leave a very uneven surface during a fall or rise of the land, though in many places this surface would be swept clean of débris.

Coniston Copper Works plateau, the pinel appears in full force. Along the north-east slope of the valley it lies on glaciated rock-surfaces, and is overlain by a deposit of sand and gravel, the latter sometimes resting on glaciated rocks. The sand and gravel here rises to a height of 200 feet above the bottom of the valley, and extends along the side of the valley, as far at least as the Copper Works, with a smooth and continuous surface, excepting where it has been rutted by rain torrents and permanent streams. It presents fine specimens of oblique lamination, and differs but very little from the middle sand and gravel of the Lancashire plains. Towards the base of the slope it attains the thickness of at least forty or fifty feet. Between the slate quarry (a short distance from the Copper Works), and the mouth of Reddale, the rounded gravel graduates into subangular and angular detritus, which, like a sloping sea-beach, runs up to the bases of the cliffs (about 1,200 feet above the sea), where it differs from recent screes by its being covered with grass. Rounded gravel on this slope may be traced up to 1,000 feet above the sea. The whole of the drift-covering of this slope, with its base of pinel, differs from any form of a glacial moraine, and up to a great height contains striated boulders, sometimes close to the surface. At the bottom of the plateau, near the Copper Works, there is a nearly level expanse of finely-laminated brown loam. It cannot be attributed to the action of the stream which here flows along the plateau, for it has not yet in many places succeeded in cutting a channel through the pinel which covers glaciated rock-surfaces in the lowest part of the valley. In other places, as at the outlet of Reddale Valley, the stream has only got a few feet beneath the level of the glaciated rocks. The laminated loam in some places rises to heights at which the stream could not have flowed since the glaciation occurred, unless in a bed consisting of drift. The laminated loam, however, is not reassorted drift, but is so associated with the lowest drift or pinel as to show that both must have been formed at the same period. It runs over the pinel, down into the pinel, is interstratified with the pinel, and runs under the pinel. It looks like the equivalent of the finely-laminated loam associated with lower boulder-clay I saw on the beach at Blackpool. In both places the laminæ are curved and waved to a remarkable extent, and here the section reveals oblique lamination, subsequent denudation, redeposition, and other indications of current-bedding. The section (Fig. 86) may be seen running along the side of the artificial channel of the stream (which in one place flows over glaciated rocks), a little below the Coniston Copper Works. Towards the north-west end of the section, the upper boulder-earth above the loam reaches a considerable thickness, and contains large striated stones. Farther NW. the laminated loam reappears. It may

Fig. 86.



AA Gravelly Upper Boulder-Earth. B Contorted Beds of Clay and Sand, with pockets of Shingle. C Coarse Sand. DDD Finely-laminated Loam. EE Hard Lower Boulder-Clay.

be traced at intervals, at higher levels, between the Coniston and Paddy End Copper Works.

From Paddy End to Greenburn.—Above Paddy End, on the side of the steep road leading to Lever's Water, there are two fine waterfalls. Lever's Water lies in a wide, deep, and nearly circular basin, hemmed in on three sides by steep slopes and cliffs rising to a height of from 1,000 to 1,300 feet above the level of the tarn, which is 1,350 feet above the sea. The invasion of the romantic solitude of Lever's Water by an artificial system of drainage, in connection with the Copper Works (for it has not only been dammed up by a stone embankment twenty feet high, but a channel has been cut through the solid rocky barrier twenty feet lower down, to provide against dry seasons), has been compensated by its revealing a partial section of the lake. It has been found that at least eighty-five feet in depth of the lake is dammed up by solid rock. On the west side of the outlet, the rocks present rounded surfaces towards the lake, but owing to the quantity of débris with which the lake-basin has been lined, I could not trace the continuation of the rocky surface down to the level of the water. After scrambling along the rough and dangerous slope which runs down into Lever's Water on its eastern shore, I had to make my way through the alternating bogs and projecting rocks of Lever's Water Bottom. Towards the northern end of this cwm-shaped valley, it became obvious that springs are raising rather than lowering the surface of the ground. Swirl Hause separates Lever's Water Bottom from Greenburn. It is a fine specimen of a high-level pass, 2,038 feet above the sea, and yet its culminating area is flat and covered with grass. On its eastern side Blacksails Peak rises to 2,443 feet above the sea, and Wetherlam beyond to about 2,500 feet. Towards the SW., Swirl Hause is connected with the peak at the head of Greenburn by a very rough and serrated rocky edge, called Prison Band. The bottom of the upper part of Greenburn Valley is comparatively flat. The fine cliffs on the western side culminate in two summits called the Carrs. One of the wonders of Greenburn is the immense assemblage of very large blocks on its south-east side, immediately under Wetherlam. Their precise mode of accumulation I was unable to determine. Many if not all of them must have fallen directly or indirectly from the rocky slopes on the south-east side of the valley, and I believe the sea as well as ice must have been instrumental in bringing them to their present positions.

Twilight Contemplations in Greenburn Valley.—The sun is setting behind the rocky summits of the Carrs. Its rays are reflected in golden lights and purple shadows from the shoulders of the giant of the Fells.* No voice of revelry intrudes into these solitudes—no indication that man has yet appeared on the earth is to be seen or heard. The observer, as he here sits beside a large fallen block,† in the twilight, might as easily fancy himself in pre-Adamite times as in the nineteenth century of the Christian era. Not only man and his works are here excluded from observation, but the atmosphere is more suggestive of eternity than time. The sublime monotonous sound, like the seugh ‡ of a distant waterfall, which in the dead of night may sometimes be heard among the abodes of men, here forces itself irresistibly on the ear. It is the sole music of this sequestered valley, and when analysed resolves itself into the combined voices of the varied forms assumed by running water in

* Wetherlam, the noblest, though not the highest of the Coniston Fells.

† Supposed to be near the middle of Greenburn Valley.

‡ A scarcely translatable Lowland Scotch word for a subdued distant sound.

its progress from the watershed to the plain. It is the audible march of 'decay'—the march of the mountain-peak to the sea—a march which is too slow for its 'infinitesimal parts' to be 'integrated' in 'time,'* but which still gives impressive evidence of its progress. Crash!—another toll of the great bell of eternity. A huge mass of rock has fallen from the opposite cliff, and added another stone to this valley of disjointed rocks; but the little unobtrusive cataract near to where it fell murmurs on as before, revealing 'the might that slumbers' in the hand of time, wasting the adamantine rock, and assisting in carrying grain after grain of the 'everlasting hills' to the unfathomable recesses of the sea. Here the voice of the volcano has long since been hushed, and the undulations of the earthquake have long since been stagnant. The sublime heights and hollows of the Tilberthwaite Fells have for uncounted ages been subjected to the fell sway of denudation. But these mountain brooks are but delegates of the Great Excavator, and the sea-waves which once undermined the towering cliffs now fading into darkness may one day resume their work of destruction, and this upland solitude, with its echoings of the past, may again be laid low beneath the surface of the yawning and never-satisfied deep.

* The words within points of quotation are from Playfair's *Illustrations of the Huttonian Theory.*

APPENDIX.

(A.)—*Inland Sea-cliffs, Beaches, and Lithodomous Perforations near Buxton* (pp. 94, 288).—At intervals all around the fine table-land called Comb's Moss, but more especially on the south-west side, flat beaches consisting of clay and loam (Upper Boulder-clay ?) run along the bases of the cliffs ; and it seems impossible to separate the cliff-forming process from that which deposited the drift, farther than by supposing the former to have been wave-action, and the latter both current and wave-action. On the east side of the Goyt Valley several distinctly-marked clay and loam beaches, backed by continuous scarps, may be easily traced. Mr. Plant, F.G.S. (as already mentioned) has described an old sea-bed consisting of fantastically-worn and deeply-indented surfaces of limestone rock, discovered by him near the summits of Grin Edge and Harper Hill. I have found similar surfaces on comparatively flat areas to the north of Buxton. Where there is a covering of clay (Upper Boulder-clay ?) it has retained the rain-water so as to enable it to roughen what were once evidently smoothly-sculptured rocks. On visiting the south side of Grin Edge, below Solomon's Temple, I very lately found four distinct old coast-lines consisting of beaches of loam and clay and rocky scarps. The lowest broad terrace I examined, had a scarp about 30 feet high ; the scarp of the second was about 20 feet high, with a beach about 30 yards in breadth, where I measured it ; terrace 3, scarp about 20 feet high, beach about 20 yards broad ; terrace 4, scarp consisting of a regular cliff-line, about 12 feet high, with a beach about 36 yards broad, and the nearly flat summit of the hill above. The transverse slope of the beaches was considerable. The detached blocks on the upper beaches, and the rocky scarps of terraces 2 and 3 were riddled with the inner ends of apparent lithodomous borings—the outer parts chipped off by frost, or perhaps partly removed by the sea before the land emerged. On the east side of the tower, on nearly the same level with the specimen found by Mr. Darbishire, F.G.S. ('Mem. Lit. and Phil. Soc. Manchester,' vol. iv. 3rd series), or about 1,400 feet above the sea, I found a block with very decided lithodomous perforations.

(B.)—*Excavation of Caves* (p. 125).—The relative share that fractures, fresh-water, and the sea may have had in the formation of caves cannot be easily assigned. As fresh-water streams could not have drilled out caves in solid rock, they must have had fractures or cavities to give a direction to their erosive action. In transverse section the channels resulting from this action would be more or less ∇-shaped. Wherever we find eroded subterranean tunnels of the shape of ⌓, or smoothly arched, we have an evidence of sea-action. During the glacial submergence the sea must have searched the remotest depths of all the caves whose entrances it did not choke up with drift. In many caves it may have denuded and deposited alternately in space and time. When the sea deposited the red loam and clay (both I believe equivalent to the Upper Boulder-clay) which covers a great part of Derbyshire, it must have left quantities of the same drift in fissures and caves. Since then fresh-water has washed down drift from the surface into caves, and fresh-water streams have washed drift out of caves. The sea-deposited drift has probably in many caves furnished the streams with more uniformly-continuous channels. As on the land, so in caves, the streams have often had enough to do to dig channels in marine drift. In many caves streams have succeeded in making channels in rock which have clearly been superimposed on the general contour of the caves. In the case of numerous caves piercing cliffs on the borders of plains, the arched porches, with inverted pot-shaped cavities, &c. (such as the truly magnificent entrance to the Peak Cavern) could only have been formed by the action of sea-waves. A stream flowing out could not have instantaneously enlarged so as to scoop out this natural vault, and round out its roof and sides. It presents the clearest indications of having been excavated by an agency assailing it from without—the agency which, before finishing its work, left the deposit of Upper Boulder-clay (?) by which the entrance is partly choked up.

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